# JOURNAL
## OF THE
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APRIL 1924

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PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

SPRING CONVENTION NUMBER

Birmingham Country Club—Open to A. I. E. E. Members and Guests during the Spring Convention.

# A. I. E. E. SPRING CONVENTION

## Birmingham, Ala.

EXCELLENT TECHNICAL PROGRAM AND INTERESTING TRIPS, APRIL 7 to 11, 1924

BIRMINGHAM, which is the center of one of the largest manufacturing and mining districts of the South, will be of special interest to engineers, because it is situated in a region of inter-connected power systems, operated by hydroelectric plants.

### TECHNICAL PAPERS

The program consists of many excellent technical papers, written particularly from the viewpoint of the operating engineer and following closely the electrical developments of this section of the country.

### TRIPS

A number of interesting trips have been scheduled, including a visit to Mitchell Dam and Lock 12, Muscle Shoals, plants of the Alabama Power Company and several industrial establishments.

### ENTERTAINMENT

A reception and several dances are features of the program and the use of two country clubs insures all kinds of outdoor sports, including golf.

Tutwiler Hotel, Birmingham, Ala.
Spring Convention Headquarters

# JOURNAL

OF THE

# American Institute of Electrical Engineers

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# Journal of the A. I. E. E.

*Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences*

Vol. XLIV APRIL, 1924 Number 4


## Excellent Paper and Interesting Trips in Spring Convention Program

PAPERS valuable especially from the operating standpoint, dealing with the problems of both power companies and industrial plants, will be the main attraction of the coming convention in Birmingham, April 7-11. In addition some very enjoyable trips and entertainments have been planned.

The location of Birmingham is particularly favorable to a profitable visit by members of the Institute. This city is situated in a region of hydroelectric developments and interconnected transmission systems, with large iron deposits on one side and coal deposits on the other, and has many industries represented by steel, textile and cement mills, foundries and others.

The technical papers which have been selected for the convention, treat of subjects closely related to these developments. Water power, transmission, circuit breakers, lightning arresters, electric furnaces, and steel-mill, mining and metallurgical applications are covered. Engineers from several sections of the country will describe the practises in their respective districts and this symposium of all current practises should be of especial value.

A notable contribution on water power development will be the addresses by prominent speakers on Tuesday afternoon and evening.

Heading the features devoted to entertainment will be an all day trip to Mitchell Dam and Lock 12 and an old-fashioned Southern barbecue. There will also be other trips to interesting places such as the plants of the Alabama Power Company, Muscle Shoals and the industrial establishments in the neighborhood.

A reception, dances, and the availability of two country clubs with excellent golf courses will add to the enjoyment of visitors.

## Proposed new Index of Transactions Papers

THE Publication Committee has for some time given thought to plans for publishing in book form an index of Institute papers published in the TRANSACTIONS. There are already available indexes covering the years 1884-1900 and 1901-1910, and there appears now to be a demand for an index covering the annual volumes published since 1910.

After a thorough consideration of the subject from various viewpoints the Committee favors the publication of an index conforming in book dimensions with the previously issued indexes, listing all papers appearing in the TRANSACTIONS 1911 to 1921 inclusive. The reason for terminating the index with the year 1921 is that the size of the TRANSACTIONS was changed beginning with the 1922 volume and it is thought that a future index may well be of the same dimensions as the present TRANSACTIONS.

It is proposed that the paper references shall be grouped chronologically under appropriate subject divisions with liberal cross-indexing, and that the Topical Index, incorporated in the two previously published indexes, be omitted. The Authors' Index will be included in full in the new volume.

Inasmuch as it is now the practise to publish in the TRANSACTIONS references to Discussion of each paper, it is believed that in the index reference to discussion may be omitted.

The Committee, through the secretary of the Institute, will be glad to receive comments or suggestions from members bearing on this important subject.

It is proposed that copies of the new index shall be sold to members at cost.

## Some Leaders of the A. I. E. E.

FRANKLIN LEONARD POPE, the second president of the A. I. E. E., was born at Great Barrington, Mass., on December 2, 1840. When he was but seventeen years of age and, after a term at the Academy, Amherst, Mass., he was employed as telegraph operator on New England lines, and later as draughtsman in the office of *Scientific American*, New York.

He reentered the telegraph service in 1861 and was rapidly advanced to a responsible position in the wire service department. In 1864 he was appointed assistant engineer and chief of the geographical department of the Western Union Russian Extension Telegraph Company, organized for the purpose of establishing telegraphic connection between American lines on the Pacific coast and the Russian overland telegraph system by way of land lines through British Columbia and cable connection across Behring Strait. After a considerable portion of the work had been completed the project was abandoned as a result of the successful laying of an Atlantic telegraph cable which established dependable connection between America and the Old World.

Mr. Pope returned to New York in October 1866, and shortly thereafter became editor of *The Telegrapher* in which position he continued until 1868 when he resigned to devote his time to furthering the new art of electrical engineering. In September 1869 the firm of Pope, Edison and Company was formed in New York, "To give professional attention to a variety of subjects involving the use of electricity, also patent applications, drawings, etc." The engineering partnership between Mr. Pope and Mr. Edison continued but a few months. One product of their joint efforts was the invention of the first one-wire telegraph stock ticker —in 1870.

In the year 1872 Mr. Pope invented devices and circuits for use in operating railroad signals by means of rail connections. From 1884 until 1890 he was part owner and editor of *The Electrician*, later *the Electrician and Electrical Engineer*, a monthly publication.

From the year 1863 until the time of his death on October 13, 1895, Mr. Pope was a foremost writer of his time on electrical subjects. His book on the electric telegraph; his papers "Life and Work of Joseph Henry," "The Inventors of the Electric Motor," and "Distribution of Electric Power at Niagara" were authoritative and were widely read.

He was a Member of the British Institution of Electrical Engineers from its inception in 1872; was one of the first vice-presidents, and the second President of the A. I. E. E., in the latter capacity serving throughout the term 1886-87.

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## University of Illinois Students to Conduct Electrical Show

AN electrical show will be conducted by the students in the Department of Electrical Engineering at the University of Illinois in Urbana, Ill., on April 24, 25 and 26.

Among the exhibits will be demonstrations of various electrical equipment including practical machines, laboratory apparatus, and devices which furnish amusement only through demonstrating the application of fundamental principles of electricity and magnetism. Many of the exhibits will be furnished by manufacturers but they will all be in charge of students.

A show of this kind is held every two years at the University. The undertaking affords the students an opportunity to gain valuable experience in organizing and the results have been thoroughly worth while to the students themselves, to building up locally the prestige of the University and for the enjoyment and education of the public which attends.

The proceeds from these shows are used for establishing a loan fund for electrical engineering students. At the last show there were about 8000 paid admissions, and a considerable sum has been accumulated for the loan fund.

## Italian Engineers Arrive in New York

IN accordance with the plan of His Excellency, Prince Caetani, the Italian Ambassador, to have a number of Italian graduate engineers come to this country with a view to giving them practical experience in the industrial organizations and plants of the country, a group of nine of these young men arrived in New York Tuesday night, February 26th. They were welcomed at the Engineering Societies Building on Wednesday morning, February 27th, by a delegation of engineers at a small meeting arranged by the Joint Conference Committee of the four Founder Societies. This group was addressed in Italian by Mr. John W. Lieb, Past President of the A. I. E. E.; Philip Torchio, Chief Electrical Engineer, New York Edison Company; Alberto Giannini, President, Italian Chamber of Commerce of New York; and F. Qualtrone, former High Commissioner. The Italian Vice Consul, P. Rossi, responded. A second group of nineteen was welcomed on March 3, and addressed by Mr. Lieb; others are expected to a total of about fifty.

Arrangements to place these men having been previously made, Consul T. F. Bernardi delivered to them envelopes of instructions to report at various places. Eleven went to the Ford Motor Company at Detroit; seven to the Westinghouse Company at Pittsburgh; four to the Foundation Company of New York; two to the Sinclair Oil Company of Philadelphia; one each to the Turner Construction Company, the Thompson Starret Company, and Warren and Wetmore, all of New York.

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## Standard for House Wiring Outlets

THE Joint Committee for Business Development, in conjunction with the Wiring Committee of the N. E. L. A. and the Association of Electragists has established a minimum standard for house-wiring outlets. Briefly stated the proposed standard is as follows:

There should be at least two circuits for each residence or apartment of five or more rooms.

In each main room, *i. e.*, parlor, living room, dining room, kitchen, bedroom, or other room used for dwelling or sleeping, there should be at least one convenience outlet and in each main hallway, bath, and pantry an additional convenience outlet is strongly recommended.

With such a standard in vogue the consumer on applying to the central station for information as to the wiring of his house would not merely be referred to the contractor, but would be advised not to consider anything less than the minimum standard as otherwise he would inevitably be obliged to make additional installations from time to time at a cost considerably in excess of an original installation.

# Effect of Certain Impurities in Storage Battery Electrolytes[1]

BY G. W. VINAL, and F. W. ALTRUP
Member, A. I. E. E.
Both of the Bureau of Standards

***Review of the Subject.***—*A new method for measuring the rate of sulphation of storage battery plates was recently devised at the Bureau of Standards by Vinal and Ritchie (Technologic Paper 225). This consisted of periodic weighings of plates suspended in electrolyte. The present paper is an extension of this work. Detrimental impurities when present in the solution may (1) corrode the plate, (2) accelerate the formation of lead sulphate, or (3) be deposited in the pores of the plate. In any case, the weight of the plate changes and this affords the most sensitive and exact means which we have for estimating the extent and nature of the reaction. A physical meaning can be given to the rather vague term "local action." It was found that electrolyte, containing only one part of platinum in ten million parts of the solution, increased the local action at the negative plates by 50 per cent. Copper, like platinum, deposits on the negative plates, but produces less effect. Iron is of unusual interest because it greatly accelerates the formation of lead sulphate at the negative plate. The reaction of the positive plates is slower, which mitigates its detrimental effects to some extent. Manganese is particularly destructive to the positive plates. The results of our experiments indicate that the reactions of manganese compounds in the battery are somewhat different from the previously accepted theories. Manganese in the form of manganese dioxide is deposited on the positive plates covering the active material, closing the pores and causing a part of the charging current to be wasted. The work is being extended to include the effect of other impurities.*

CONTENTS



## Introduction

THE importance of obtaining exact information about the effect of impurities in storage battery electrolytes arises from the detrimental effects which many of them produce on the operating characteristics and life of the storage battery, and such information is necessary as a basis for the preparation of specifications for sulphuric acid to be used in the batteries. Engineers have recognized for a long time the necessity for maintaining a high standard of purity in the electrolyte, but within recent years millions of small batteries have passed into the hands of non-technical users who must depend upon the manufacturer and his subsidiaries for satisfactory service. The information hitherto available on this subject has been fragmentary and in some cases contradictory.

The most recent systematic research on this subject is that of Helen C. Gillette.[2] Her experiments were carried out by the method used by several previous experimenters, *i. e.*, by poisoning the cells after their electrical characteristics had been determined. This method, while valuable from the standpoint of operation does not permit us to determine quantitatively the effects produced on the positive and negative plates or to determine definitely the chemical reactions which take place.

A new method for measuring the rate of sulphation of storage battery plates was recently devised at the Bureau of Standards. A description of this method with experimental results for measurements on positive and negative plates suspended in pure sulphuric acid solutions has been published.[3] The same method and apparatus have been employed in the present investigation but with some modifications necessitated by the conditions of our experiments. In this paper the effects of small amounts of iron, maganese, platinum and copper are described.

## II. Principle and Method

The discharge of either the positive or negative plates in sulphuric acid solutions results primarily in the formation of lead sulphate. A certain amount of lead sulphate is formed as the result of local action when the plates are immersed in even the purest acid solutions obtainable. Detrimental inpurities may (1) corrode the plate, (2) accelerate the formation of lead sulphate, or (3) be deposited in the pores of the plate. In any case the weight of the plate changes and this change affords the most sensitive and exact means which we have for estimating the extent of the reaction. In order to obtain comparable results it is necessary that the temperature be maintained at a constant value. This was usually accomplished by immersing the glass jars containing the electrolytes in a large water bath thermostatically controlled at 25 deg. cent. (77 deg. fahr.).

1. Prepared under the Auspices, and published with the approval of the Bureau of Standards.

2. Transactions American Electrochemical Society 41, p. 217, 1922.

*To be presented at the Spring Convention of the A. I. E. E., Birmingham, Ala., April 7-11, 1924.*

3. Vinal and Ritchie, Bureau of Standards, Tech. Paper 225. *Chem. & Met.*, v. 27, p. 1116, *Electrical World*, v. 80, No. 26, p. 1383.

This temperature was maintained constant to within about 0.01 deg. cent. Two positive plates or two negative plates, suspended on glass hooks were placed in each jar. As a preliminary step the plates were given several cycles of charge and discharge following which they were fully charged and then submerged in the electrolytes to be tested. Each jar contained a solution of chemically pure sulphuric acid having a specific gravity of 1.250. The electrolytes were saturated with lead sulphate because the previous work showed this to be necessary.

A sensitive balance mounted on a marble slab above the thermostat bath was used for weighing the plates while they were immersed. Any plate could be brought

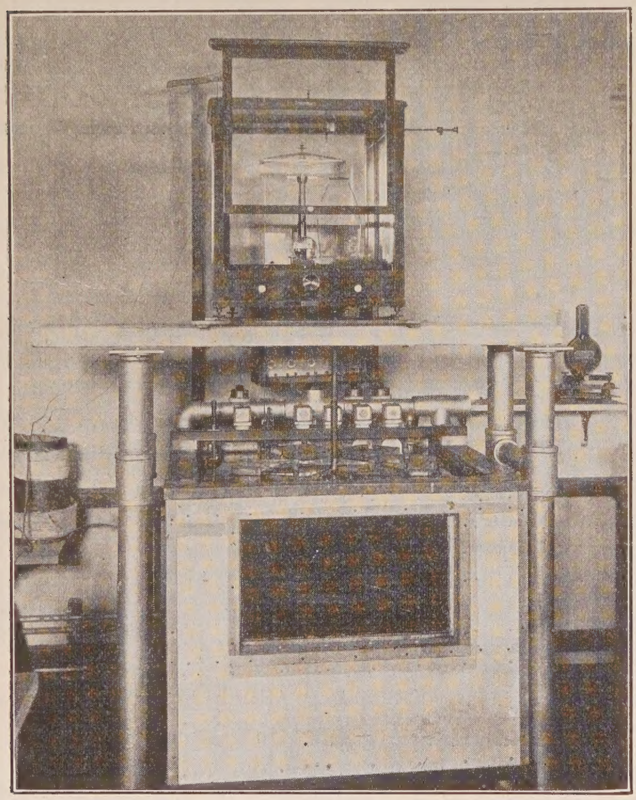

Fig. 1—Apparatus for Testing Batteries

directly under the arm of the balance, as the jars containing them were carried on a revolving frame. The arrangement of the apparatus is shown in Fig. 1.

A carefully measured quantity of the impurity was added to the electrolyte in each case before the plates were immersed. Simultaneously with the tests to determine the effect of the impurities, measurements were made of the rate of sulphation of the plates in pure solutions. The results of the experiments are shown by means of curves relating the total change in weight of the plates to the time in hours. Weighings of the plates were taken immediately after placing them in the solutions and they were weighed at frequent intervals during the first day because the rate of the reaction was generally the greatest at this time. As the reaction slowed down weighings were made at less frequent intervals.

A distinction must be made between the rate and the total extent of the reactions produced by the impurities. In the case of impurities such as platinum and copper the rate of the reaction is of interest because the reaction, if allowed to proceed indefinitely, will be terminated only by the complete exhaustion of the plates. On the other hand with an impurity such as iron the total extent of the reactions is limited by the amount of the impurity added and any spontaneous oxidation or reduction which may occur. In such a case, therefore, the total reaction is of more interest than the rate of the reaction since it permits us to verify the chemical equations for the reactions that occur.

The concentrations of the impurities are expressed as percentages by weight.

## III. Effect of Copper

Copper was added to the solutions of sulphuric acid saturated with lead sulphate in the concentrations shown in Table I. The solutions initially had the characteristic blue color of copper sulphate. When the two negative plates were immersed in the solutions the copper began to deposit upon the plates and the solutions gradually lost color. An analysis of the solutions after the experiment was completed showed only a small trace of copper. This shows that practically all the copper had been deposited upon the plates. Since the amount of solution in which they were immersed greatly exceeded the amount of solution that would ordinarily be present in a battery, the amount of copper deposited on each plate was in excess of that which would be found in ordinary practise. The quantity of solution was approximately ten times the amount that would be contained for the same number of plates, in a starting and lighting battery. To obtain equivalent conditions, therefore, in the case of those impurities which deposit upon the plates the concentrations should be multiplied by a factor of 10.

TABLE I

LOCAL ACTION PRODUCED BY COPPER AT NEGATIVE PLATE

Concentrations of copper are shown in the box headings. Results are calculated as ampere-hours of equivalent discharge for one plate.

| Time in Hours | Copper Concentration, 0.4 | 0.08 | Per Cent Pure Acid |
|---|---|---|---|
| 10 | 0.8 | 0.1 | 0.0 |
| 20 | 2.1 | 0.2 | 0.1 |
| 30 | 2.9 | 0.3 | 0.2 |
| 40 | 3.6 | 0.5 | 0.3 |
| 50 | 4.1 | 0.6 | 0.4 |
| 75 | 5.2 | 0.9 | 0.5 |
| 100 | 6.0 | 1.2 | 0.7 |
| 150 | 7.4 | 1.7 | 1.0 |
| 200 | 8.7 | 2.2 | 1.4 |
| 300 | 10.9 | 3.4 | 2.0 |
| 400 | 13.1 | 4.5 | 2.6 |

The deposition of the copper upon the negative plates could be easily seen. An illustration of one of these

plates, together with a similar plate taken from a pure acid solution, is shown in Fig. 2.

The local action which occurred at the plate as the result of the deposition of copper was accompanied by the evolution of hydrogen. The changes in weight of the plate during the process are shown in the curves of Fig. 3, and from these we have computed the equivalent of the local action in ampere-hours as the average value per plate. The results of the calculation are

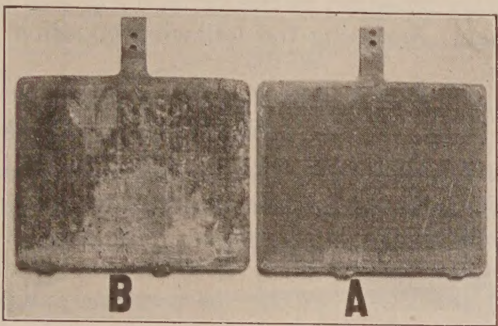


Fig. 2—Negative Plate (B) Contaminated with Copper—Plate (A) was Taken from a Pure Solution

given in Table I. The ultimate capacity of the plate has been calculated from the amount of active material contained in the plate allowing for 60 per cent sulphation. Since the plate contained 148 grams of the active negative material the ultimate capacity is calculated to be 22.9 ampere-hours.

Table I shows that during the first part of the experiment the extent of the local action produced by the

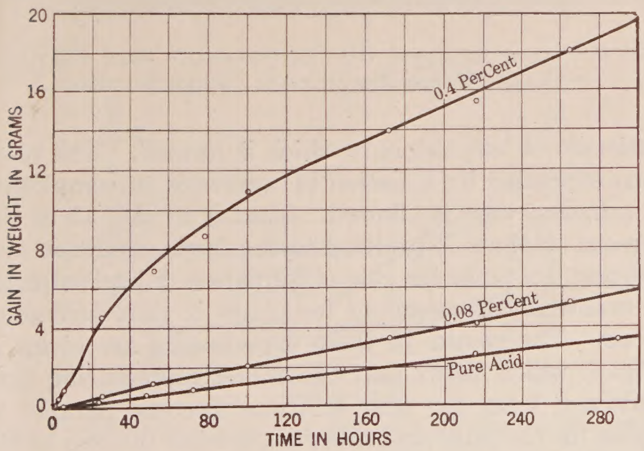


Fig. 3—Effect of Copper on Negative Plates

copper is not as great as might be expected. This is probably due to the rather high overvoltage for hydrogen on the surface of copper. The solution which contained 0.08 per cent of copper produced approximately double the amount of local action that was observed in the case of the plates immersed in the pure solution. The total number of ampere-hours of equivalent discharge at the end of 400 hours, however, was only one-fifth of the ultimate capacity of the plates.

The solution containing 0.40 per cent copper produced an equivalent discharge of 13 ampere-hours per plate in a period of 400 hours. This is about half of the ultimate capacity of the plates.

## IV. Effect of Platinum

Platinum has always been considered one of the most deleterious impurities. The results of this investigation amply justify this conclusion. Platinum, however, is not as common an impurity at the present time as it has been in the past, because comparatively little sulphuric acid is now concentrated in platinum vessels during the process of manufacture.

Platinum was added to the sulphuric acid solutions, as in the case of copper, in the percentages shown in Table II. The experimental results are given in Fig. 4.

The platinum evidently began to deposit upon the negative plates very quickly as they began to gas almost

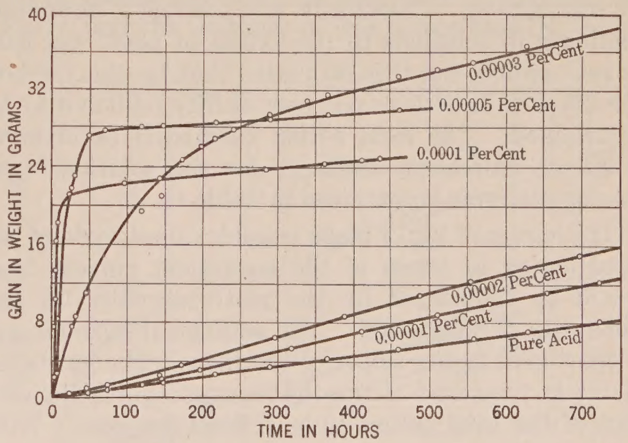


Fig. 4—Effect of Platinum on Negative Plates

TABLE II

LOCAL ACTION AT NEGATIVE PLATE PRODUCED BY PLATINUM

Results are calculated as ampere-hours of equivalent discharge per plate

| Time in Hours | Platinum Concentrations, Per Cent | | | | | |
|---|---|---|---|---|---|---|
| | 0.0001 | 0.00005 | 0.00003 | 0.00002 | 0.00001 | Pure Acid |
| 10 | 11.4 | 6.7 | 2.0 | 0.1 | 0.0 | 0.0 |
| 20 | 11.7 | 10.6 | 3.7 | 0.2 | 0.1 | 0.1 |
| 30 | 11.9 | 13.0 | 5.2 | 0.3 | 0.2 | 0.2 |
| 40 | 12.0 | 14.5 | 6.4 | 0.4 | 0.3 | 0.3 |
| 50 | 12.0 | 15.3 | 7.4 | 0.5 | 0.4 | 0.4 |
| 75 | 12.2 | 15.6 | 9.3 | 0.8 | 0.6 | 0.5 |
| 100 | 12.4 | 15.7 | 10.8 | 1.1 | 0.8 | 0.7 |
| 150 | 12.8 | 15.9 | 13.1 | 1.7 | 1.2 | 1.0 |
| 200 | 13.1 | 16.1 | 14.6 | 2.3 | 1.7 | 1.4 |
| 300 | 13.5 | 16.3 | 16.7 | 3.6 | 2.7 | 2.0 |
| 400 | 13.9 | 16.4 | 18.1 | 5.0 | 3.8 | 2.6 |
| 500 | | 16.5 | 19.1 | 6.2 | 4.7 | 3.2 |
| 600 | | | 19.8 | 7.3 | 5.7 | 3.7 |
| 700 | | | 20.5 | 8.3 | 6.6 | 4.3 |
| 800 | | | 21.0 | 9.3 | 7.4 | 4.8 |
| 900 | | | 21.4 | 10.2 | 8.2 | 5.4 |
| 1000 | | | 21.8 | | | 5.9 |

immediately. The plates in solutions containing the greatest amount of platinum gassed violently and increased in weight very rapidly. The gassing was so

violent that the surface of the plates was apparently blasted off and most of the platinum thereby eliminated. With the highest concentration the plates became about 60 per cent discharged within eight hours, but after this the rate of their discharge was comparatively slow. The reaction was not quite so violent in the solutions containing the next lower percentage of platinum but it is significant that the reaction proceeded farther. At the end of 48 hours the plates were 72 per cent discharged. The solution containing 0.00003 per cent of platinum produced a reaction which was much slower but produced 95 per cent of the ultimate discharge in 1000 hours. The lower concentrations produced smaller effects but the gain in weight was appreciably greater than with pure acid. One part in ten million, or 0.00001 per cent platinum produced an increase of 50 per cent in the local action over that in pure acid solutions, which shows that the effect of extremely small amounts of platinum may be detected by this method. Chemically, it is possible to determine platinum in solutions to the extent of about one part in two million, but it is estimated that by this method the effect of as little as one part in fifty million may be determined. The local action calculated as ampere-hours of equivalent discharge for the solutions containing platinum is contained in Table II.

The curves of Fig. 4 make possible an estimate of the local action in terms of the equivalent current that would be discharged by the plate normally for the same rate of sulphation. The equivalent currents are proportional to the slopes of the lines. The curve for plates in pure acid shows the average equivalent current of the local action to be 0.0059 amperes. With this as a basis the equivalent currents during the first part of the experiment for the other curves have been calculated to be as follows:

| Platinum Concentration | Current Equivalent of Local Action |
|---|---|
| Per Cent | Amperes |
| 0.00001 | 0.0093 |
| 0.00002 | 0.0113 |
| 0.00003 | 0.107 |
| 0.00005 | 0.345 |
| 0.00010 | 1.71 |

By this calculation a physical meaning is given to the rather vague term "local action."

The plates which gassed most vigorously and from which the original lead surface was blasted off were black for the most part but showed portions covered by the white lead sulphate. The black coloration was probably due to the lamp black which was mixed with the paste when the plates were made. An illustration of one of these plates as compared with one immersed in a pure sulphuric acid solution is shown in Fig. 5.

## V. Effect of Iron

Iron may exist in the sulphuric acid solutions in two states of oxidation. Iron in the ferric condition is reduced to the ferrous condition at the negative plate and then in turn oxidized to the ferric condition at the positive plate, and also to some extent by the air.

(a) *Effect on positive plates.* When iron in the ferrous condition is added to the solution it is oxidized by the active material of the positive plates to ferric sulphate accompanied by the formation of lead sulphate and water. Assuming the following equation for the reaction

$$Pb\,O_2 + 2\,Fe\,S\,O_4 + 2\,H_2\,S\,O_4 \rightarrow Pb\,S\,O_4 + Fe_2\,(S\,O_4)_3 + 2\,H_2\,O \qquad (1)$$

The lead sulphate which is formed permits an accurate calculation to be made of the extent of the reaction from the gain in weight of the plates. The gain in weight of the positive plates must, however, be calculated as $Pb\,S\,O_4$: $(Pb\,S\,O_4 - Pb\,O_2)$, because the plate gains the sulphate radical $S\,O_4$ as the result of the reaction but loses simultaneously two oxygen atoms for each

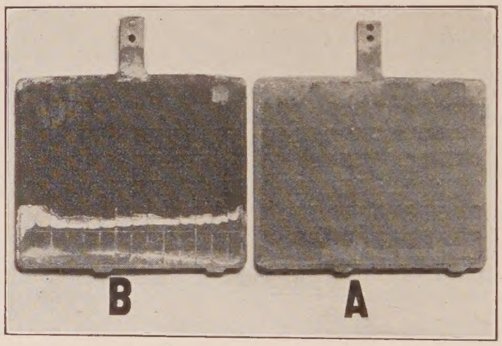


Fig. 5—Negative Plate (B) Contaminated with Platinum—Plate (A) was Taken from a Pure Solution

molecule of lead sulphate which is formed. The reaction expressed by equation (1) proceeds to completion if sufficient time is allowed. That is to say, all of the ferrous sulphate is oxidized to the ferric condition and beyond this point the rate of formation of lead sulphate is essentially the same as for plates in pure acid solutions. The results of these experiments are given in Fig. 6, which shows that the curves representing data obtained from the iron solutions become parallel to those for the pure acid solutions toward the end of the experiment. We may therefore, calculate the amount of lead sulphate which should be formed and compare it with the amount determined by the weighings. Such a comparison is made in Table III.

The agreement is as good as can be expected. The curves shown in Fig. 6 show the average gain in weight per plate and the figures given in Table III represent the sum total of the lead sulphate formed on both plates in each jar.

Since the reaction expressed in equation (1) came to

TABLE III
COMPARISON OF CALCULATED AND OBSERVED VALUES FOR POSITIVE PLATES IN SOLUTIONS CONTAINING IRON

| Amount of Iron Added | | Equivalent Ferrous Sulphate | Calculated Equivalent Lead Sulphate | Observed Amount of Lead Sulphate |
|---|---|---|---|---|
| Per Cent | Grams | Grams | Grams | Grams |
| 0.4 | 22.5 | 61.2 | 61.2 | 60.2 |
| 0.08 | 4.5 | 12.2 | 12.2 | 11.8 |
| 0.012 | 0.675 | 2.7 | 2.7 | 3.4 |

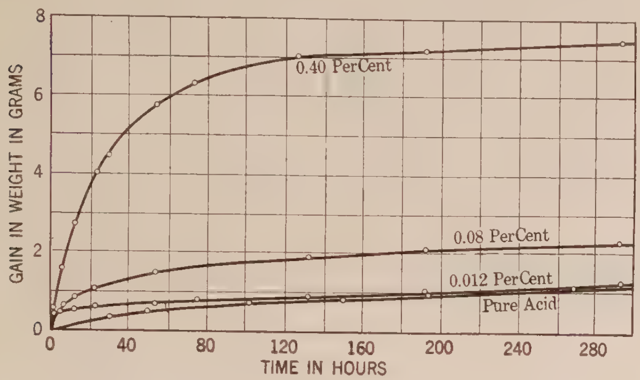


FIG. 6—EFFECT OF IRON ON POSITIVE PLATES

a definite termination this afforded an excellent opportunity to determine what the effect of introducing negative plates into the solution would be. This case represents the condition of a battery containing both positive and negative plates. One charged negative plate was immersed in each solution at the conclusion of 360 hours. These plates were not in electrical contact with the positive plates. The reduction of the iron to the ferrous condition began immediately and the

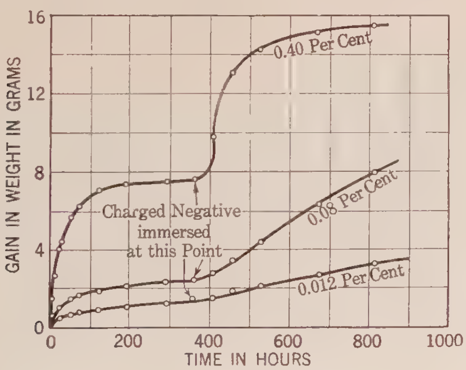


FIG. 7—GAIN IN WEIGHT OF POSITIVE PLATES IN SOLUTIONS CONTAINING IRON

product in turn was reoxidized by the positive plates accompanied by a further discharge. Curves showing the observations which were made are given in Fig. 7, the experiment being continued until 820 hours had elapsed.

(b) *Effect on negative plates.* The action of iron on the negative plates is much more pronounced than on the positives and the local action produced is in excess of the amount which would be calculated from the reduction of the ferric sulphate. The effect is probably the result of two simultaneous reactions that may be represented by the following equations:

$$Pb + Fe_2\,(S\,O_4)_3 \rightarrow Pb\,S\,O_4 + 2\,Fe\,S\,O_4 \qquad \textbf{(2a)}$$

$$Pb + H_2\,S\,O_4 \rightarrow Pb\,S\,O_4 + H_2 \qquad \textbf{(2b)}$$

The amounts of iron added to the solutions were 4.5 g. and 0.675 g. These are equivalent to 16.1 g. and 2.4 g. of ferric sulphate. On the basis of equation (2a) these amounts will account for 13.4 and 2.0 grams of lead sulphate respectively.

The curves, Fig. 8, show the gain in weight of the plates in terms of the sulphate $S\,O_4$ taken from the electrolyte. This gain in weight calculated to lead sulphate $P\,b\,S\,O_4$ is greatly in excess of what may be accounted for by the reduction of the iron salt from the ferric to the ferrous condition. The curves show also that the gain in weight of the plates in the solutions to which iron had been added is in excess of the sulphation of similar plates in the pure acid. This indicates clearly that the presence of iron accelerates the action

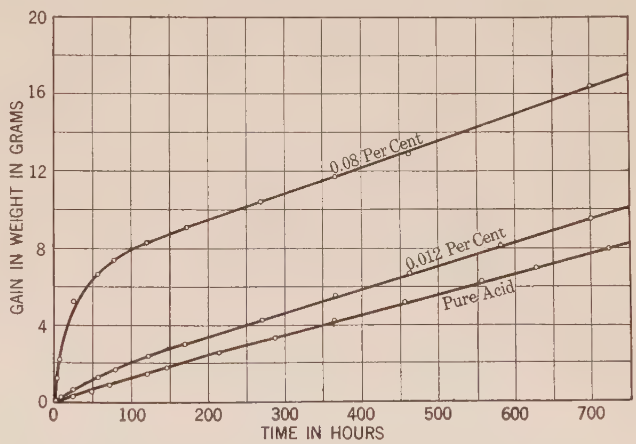


FIG. 8—EFFECT OF IRON ON NEGATIVE PLATES

between sulphuric acid and lead as represented by equation (**2b**).

In the early stages of the experiment when considerable ferric iron was present this reaction was greatly accelerated as shown by the rapid rise in the curves. When 150 hours had elapsed this accelerating effect of the iron seems to have died out and the curves then become straight and follow an almost parallel course with the curve representing the sulphation of pure acid. If we assume that the reduction of the ferric sulphate according to equation (**2a**) has become complete at this point, we may calculate an average value for the amount by which the reaction between lead and sulphuric acid has been accelerated. In the solution containing the greater concentration of iron the increase over the normal sulphation in pure acid is about 7 times and in the other solution about 3 times.

After 150 hours the curves shown in Fig. 8 are all approximately straight, but they diverge slightly which shows that sulphate was being formed at a slightl

greater rate on the plates in the solutions to which iron was added than in the pure acid. This effect is probably to be accounted for by the well known slow spontaneous reoxidation of the ferrous sulphate by the air and its subsequent reduction by the negative plates during the long time that the experiment lasted.

Table IV shows the gain in weight of the plates in the solutions to which iron had been added in comparison with the gain in weight of similar plates in pure acid solutions. There were two plates in each jar and the total gain of each pair of plates is shown in the table. Fig. 8 shows the average values.

TABLE IV
EFFECT OF IRON ON NEGATIVE PLATES
The weights are the total gain of the two plates in each case, expressed in grams

| Hours | Iron Concentration, Per Cent 0.08 | 0.012 | In Pure Acid |
|---|---|---|---|
| 10 | 4.36 | 0.60 | 0.20 |
| 20 | 8.80 | 1.10 | 0.48 |
| 30 | 10.80 | 1.58 | 0.76 |
| 40 | 12.00 | 2.00 | 1.00 |
| 50 | 12.94 | 2.40 | 1.24 |
| 75 | 14.26 | 3.26 | 1.94 |
| 100 | 15.80 | 4.04 | 2.50 |
| 150 | 17.60 | 5.48 | 3.64 |
| 200 | 19.00 | 6.86 | 4.72 |
| 300 | 21.70 | 9.58 | 7.12 |
| 400 | 24.30 | 12.00 | 9.30 |
| 500 | 27.00 | 14.24 | 11.44 |
| 600 | 29.64 | 16.62 | 13.46 |
| 700 | 32.40 | 18.80 | 15.40 |
| 800 | 35.00 | 20.84 | 17.26 |

In addition to the above experiments a third concentration of the iron, 0.004 per cent, was used. The results were about the same as for 0.012 per cent and as the curves would lie so near together only one of them has been plotted in the figure. The reason that the smaller amount of iron produced the same amount of sulphation as the larger amount is probably to be attributed to the spontaneous reoxidation of the ferrous sulphate.

The results of this experiment show that the presence of iron is more detrimental to negative plates than to positives because of the acceleration of the reaction between lead and sulphuric acid. Further, the ferrous sulphate which is formed suffers a slight reoxidation by air, in addition to that which would be caused by the positive plates present in a battery.

## VI. Effect of Manganese

(a) *Effect on negative plates.* The experimental results obtained when negative plates were immersed in solutions containing manganese are shown in Fig. 9. The lowest curve represents the sulphation of the plates in pure acid solutions. The three curves above this are for similar solutions to which were added respectively 0.04 per cent, 0.08 per cent, and 0.40 per cent of manganese as potassium permanganate.

It is at once apparent that the effects produced are not proportional to the amounts of manganese added. The reason for this is a reaction between the sulphuric acid and the potassium permanganate which is independent of the reaction at the plates. The reaction between the permanganate and the 1.250 sp. gr. acid may be expressed by the equation

$$4\ K\,Mn\,O_4 + 6\,H_2\,S\,O_4 \rightarrow 2\,K_2\,S\,O_4 + 4\,Mn\,S\,O_4 + 6\,H_2\,O + 5\,O_2 \qquad (3)$$

This is a slow reaction that may be demonstrated by a simple laboratory test, several hours being required to collect enough of the oxygen to make a satisfactory test. During the experiments the gas (oxygen) given off appeared in small amounts over the entire surface of the liquid. It was not localized at the plates.

The reactions which take place at the plates in contradiction to the above reaction, which occurs whether the plates are present or not, results in decolorizing the permanganate and in the formation of lead sulphate and manganese dioxide. The reactions are not fully understood, but the following equation, which

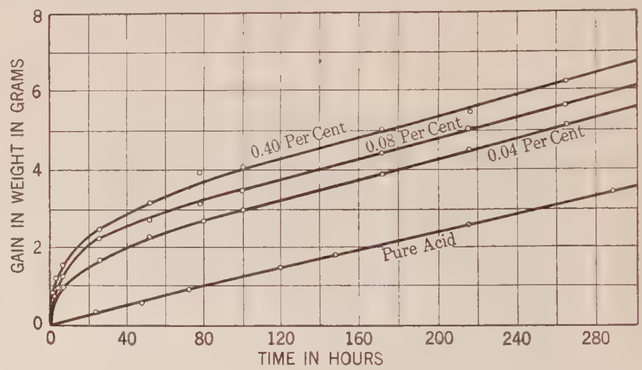


Fig. 9—Effect of Manganese on Negative Plates

is in accordance with the observed facts is believed to represent the reaction:

$$2\,K\,Mn\,O_4 + 4\,H_2\,S\,O_4 + 3\,Pb \rightarrow K_2\,S\,O_4 + 2\,Mn\,O_2 + 3\,Pb\,S\,O_4 + 4\,H_2\,O \qquad (4)$$

There are probably several intermediate reactions which take place before the end products are reached. A sludge fell to the bottom of the jar which was tested and found to be hydrated manganese dioxide. Possibly some of the manganese was converted into manganous sulphate. No gassing was visible at the plates. The equation indicates that three molecules of lead sulphate result from the reduction of 2 molecules of permanganate. The data given by the curves in Fig. 9 do not account for the amount of lead sulphate that would be expected. This is because of the spontaneous reaction expressed by equation (3) above. The permanganate in our experiments was added 18 hours before the plates were put in since we did not anticipate this reaction. The curves show a rapid sulphation of the plates for about 50 hours. Then the solution became decolorized and the curves became parallel to the curve representing the sulphation of the plates in

pure acid. The curves continued parallel during the remaining 250 hours of the experiment. The parallelism of these curves indicates that the reaction has become complete and that the manganese has been reduced to manganese dioxide and precipitated.

(b) *Positives in solutions containing manganese.* The manganese was added to the solutions as manganous sulphate, $MnSO_4$. The solutions were initially colorless but began to show a purple coloration almost

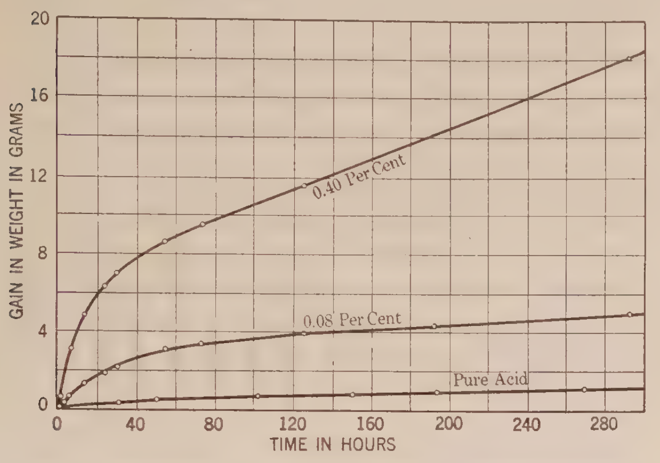


Fig. 10—Effect of Manganese on Positive Plates

immediately after the positive plates were immersed. This indicates the formation of permanganic acid, $HMnO_4$, probably according to the equation

$$5\,PbO_2 + 2\,MnSO_4 + 3\,H_2SO_4 \rightarrow 2\,HMnO_4 + 5\,PbSO_4 + 2\,H_2O \quad (5)$$

The solutions containing 0.4 per cent of manganese became so dark within one hour after the plates were immersed that the plates were no longer visible.

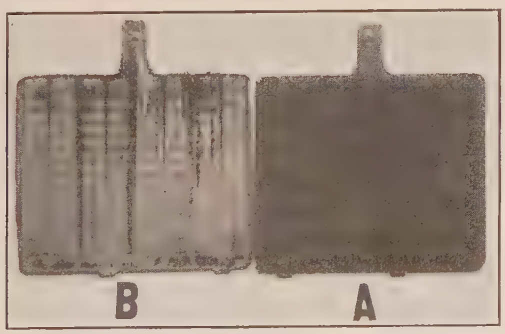


Fig. 11—Positive Plates showing Deposit of Manganese Dioxide

A rapid gain in weight of the plates was observed as shown in Fig. 10. Comparing the results for both positives and negatives obtained in solutions with 0.08 per cent of manganese it was found that the gain of the positives was much larger as a result of the oxidation of the manganous sulphate than the gain of the negatives resulting from the reduction of permanganate in the same length of time. After the rapid gain during the first 50 hours, the plates continued to gain in weight at a rate somewhat more rapid than for similar plates in the pure acid solution. The rate of the gain, however, steadily decreased indicating that the reactions were becoming complete.

A deposit was formed on the plates, the sides of the glass jar, and to some extent on the surface of the liquid. The deposit on the plates after drying was a dull sooty black which filled the pores of the plates and the excess formed a rough spongy layer over most of the plate surface also. Two plates are shown in Fig. 11. Chemical analysis showed that this deposit was manganese dioxide, $MnO_2$. It seems probable that the gain in weight of the plates during the first period of perhaps 50 hours is largely the lead sulphate formed as a result of oxidizing the manganous sulphate, but an important part of the total gain in weight is due to manganese

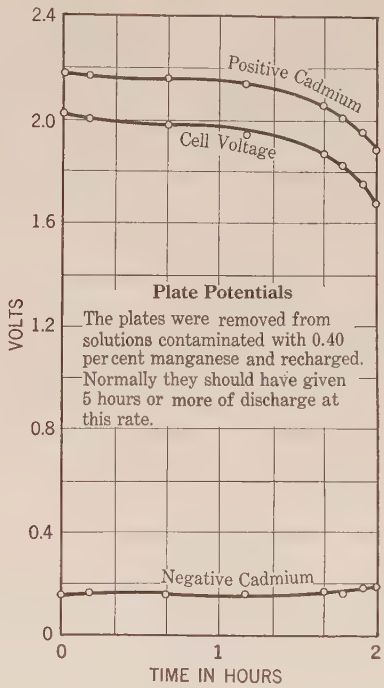


Fig. 12

dioxide deposited in the pores and on the surface of the plate. Our experiments do not permit us to estimate the relative amounts of each.

Since the tendency of the negative plates is to throw the manganese out as a sludge it might appear that the effects of manganese would gradually disappear. This, however, is not the case as the experiments of Helen C. Gillette[4] have shown. The reason for the destructive effects of manganese are to be found in the reactions at the positive plates.

The manganese dioxide deposited upon the positive plates fills the pores of the active material and covers the plate with a non-conducting hard film in a highly oxidized state. We took two of the plates, a positive and a negative upon which weighings had been made

4. *Loc Cit.*

and immersed them in pure acid solution of specific gravity 1.250 and passed a charging current through them beginning with a rate somewhat below the normal finishing rate of charge. The positive began to gas immediately. Raising the charging rate to the normal value increased the gassing and the electrolyte, initially clear, began to show a purple coloration indicating the re-formation of permanganic acid. The reaction at the positive during charge might be expressed by the equation

$$2\,Mn\,O_2 + 3\,O + H_2\,O \rightarrow 2\,H\,Mn\,O_4 \qquad (8)$$

This reaction at the positive occurred more rapidly than the reduction at the negative as shown by the increasing coloration of the electrolyte due to permanganic acid. With the re-formation of permanganic acid by the charging process the battery is again put in condition for a repetition of the reactions represented by the equation (**5**). It should be noted that the equation for charging makes no provision for the oxidation of the lead sulphate at the positive plate. Plates that are heavily coated with $Mn\ O_2$ can receive but little charge. The pores are stopped and part of the energy is expended in the reaction on the manganese dioxide and part in the liberation of excess oxygen which normally would oxidize the lead sulphate.

After the plates had been charged, a discharge of them was made using a cadmium electrode to measure the plate potentials. These are shown in Fig. 12. These plates were discharged at the normal 5-hour rate. The positive plates, however, gave out at the conclusion of two hours. It is quite evident from an examination of the plates that the pores were stopped and that the plates could not be fully charged.

## VII. Conclusion

In the case of four impurities, copper, platinum, iron, and manganese, it has been possible to determine quantitatively the effects produced by various concentrations of the impurities and to indicate to a fair degree of certainty the nature of the chemical reactions produced. In interpreting these data, particularly with reference to the drafting of specifications for sulphuric acid, two factors must be borne in mind. One of these relates to the extent of the deleterious effects produced by the impurities and the other to the amounts of the impurities which are present in the acid as produced under normal manufacturing conditions.

In the case of platinum it was shown that the presence of one part in ten million increases the local action 50 per cent over that which is found in the case of pure acid. This amount is below that which can be determined by ordinary chemical methods. The obvious conclusion, therefore, is that no platinum whatever should be allowed by the specifications. This condition can be met by the acid manufacturers at the present time.

Copper by itself produced less effect than was anticipated. It is not desirable, however, that the amount of copper to be permitted by the specifications should be raised to as large a figure as the results of these experiments might indicate to be permissible; because (1) such an amount would be unnecessarily large and in excess of the amount found in acid of good quality, (2) because copper in combination with certain other impurities is believed to be very detrimental.

Iron presents unusual interest because of its accelerating effects on the reactions at the negative plate. These experiments show that the presence of iron affects the negative plate more severely than the positive. Iron will, therefore, tend to exist in the ferrous condition in the battery and its activity is limited by the rather slow rate at which it is oxidized to the ferric condition by the positive plate and by air. Since the negative plates ordinarily exceed the positive plates in capacity the effect of iron may be minimized. Iron is, therefore, in the same category with copper in that the maximum amount to be permitted by the specifications should be determined by manufacturing conditions rather than by the effects which it produces in the battery.

Manganese deposits upon the positive plates and produces serious effects. It covers the active material of the plate, closes the pores and causes a large amount of charging current to be wasted as gas. Although the manganese is deposited on the positive plate it does not remain there, since during the charging process part of it is thrown back into the solution as permanganic acid. The results show that manganese in the electrolyte must be kept at the lowest possible figure.

This work is being extended to include the effect of other impurities. We are indebted to Drs. Blum and Lundell of the Bureau of Standards for valuable suggestions about the chemical reactions involved in this work.

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## LECTURES ON ELECTRICAL SUBJECTS IN AKRON, OHIO

The engineering school of the Akron, Ohio, University, conducts evening classes in technical subjects which are attended regularly by students who are employed during the day time.

In order to extend the instruction so that those who are unable to attend regular classes may still have the opportunity to benefit from occasional lectures, the University and the Board of Education of the city are cooperating in the undertaking of providing a series of talks on technical subjects to be given in public school auditoriums where blackboards and stereopticon equipment are available.

These lectures are largely attended by contractors, electricians, workmen and electrical students. The lectures are well advertised in advance and the attendance usually is quite large.

A recent lecture of this course was given by Mr. Verne W. Shear, of Verne W. Shear & Company, Akron, his subject being "Transformers."

# The Nature of Language[1]

## A Resumé of Recent Work on the Physics of Speech and Hearing

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***Review of the Subject.***—*In introduction, the history of human language is outlined and the manner of speech production is briefly described with special reference to English. Following this is a summary treatment of available data on the subject of speech and hearing. Much of this is the result of investigations carried out during the last two or three years in the Research Laboratories of the Bell System at New York.*

*Human speech employs frequencies from a little below 100 cycles per second to above 6000 cycles, a range of about six octaves. The ear can perceive sound waves ranging in pressure amplitude from less than 0.001 of a dyne to over 1000 dynes and in frequency of vibration from about 20 cycles per second to about 20,000, a range at about ten octaves.*

*The intensities and frequencies used most in conversation are those located in the central part of the area of audition. The energy of speech is carried largely by frequencies below 1000, but the characteristics which make it intelligible, largely by frequencies above 1000. Under quiet conditions good understanding is possible with undistorted speech having an intensity anywhere from one hundred times greater, to a million times less than that at exit from the mouth. On the whole the sounds, th, f, s, and v are hardest to heat correctly and they account for over half the mistakes made in interpretation. Failure to perceive them correctly is principally due to their very weak energy although it is also to be noted that they have important components of very high frequency.*

* * * * *

PRIMITIVE man, when he wished to communicate, probably expressed himself by grimaces, vocal sounds, and gestures. Although each of these three agencies is still somewhat employed, the combination of voice and ear has been subconsciously evolved and has survived as economical, most flexible in its capacity for variation, and superior in perceptibility.

According to modern philologists, early utterances were song-like and poetic accompaniments of excited or pleasurable emotion, rich in sound and rhythm but without very definite meaning. The motives for utterance gradually changed, the process of associating sense with sound began, and speech and song came to be differentiated.

Primitive languages, in general, consisted mostly of long words with many difficult sounds. Certain exclamatory sounds came readily to designate personal feelings. Echo words, mimicing nature, came to designate natural sounds or the manner or source of their production. Names of persons and objects were an early development. Most words however have had a more obscure and complex history. Evolution has tended to shorten word forms and to drop sounds hard to pronounce or to hear.

As man's powers of analysis have developed language has become more flexible and capable of greater range of expression. The grammar of language in general has become simpler and more systematic.

Men in different parts of the earth have evolved differentiated languages, any one of which is now based hardly at all upon natural suggestiveness but rather upon traditional understandings gradually accumulated. Each language has its own system of elementary speech sounds. Since only a limited range and variety of sounds can be spoken, it is natural that there should be many similarities between the speech sounds of different languages. The elementary sounds of a given tongue are combined into syllables and words, and these in turn joined together into phrases to convey ideas, all according to the mutual conventions of the people who use the language.

The voice alone enabled man to communicate under circumstances where his gestures could not be seen and at distances beyond where his facial expression could be made out. In our own times the invention and development of the telephone has marked a new step in the evolution of human society, extending the vocal range of man to extraordinary degrees. Voices are hourly carried with instant speed from one end of the land to the other and it is now possible for a speaker to address at one time a million persons gathered about him or scattered at distant points. Speech is the load which the telephone system transports, and the ear is the consumer of the product. Alexander Graham Bell, inventor of the telephone, as student and professor of vocal physiology gained a deep insight into the mechanism of operation of the voice and ear before his greatest invention was made. Throughout his life he devoted himself to the alleviation of the infirmities of the deaf and the dumb. Interest in the problems of speech and hearing comes naturally, therefore, to the telephone organizations which bear his name by sentiment as well as by the needs of their practise.

This paper refers briefly to the mechanism of speech and hearing and then describes some of the physical data of oral communication which have been obtained by investigations carried on during the past few years. A selected bibliography of published papers is attached. Much of the material brought together and summarized here has appeared in scattered form in the articles referred to.

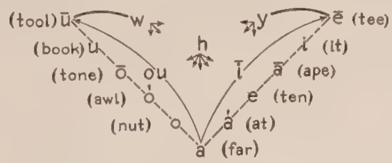
The organs of speech are the lungs, which by their bellows-like action function as a motor element to supply streams of air which pass in and out through the

1. *Presented before the following Sections of the A. I. E. E., Milwaukee Section, January 11, 1923; Cleveland Section, January 23, 1923; Washington Section. February 13, 1923.*

vocal passages. The vocal cords, the tongue and lips, and the cavities of the mouth, nose, and throat, impress on the air flow variations which are heard as sounds. The vocal cords are a pair of muscular ledges on opposite sides of the larynx which can be stretched and brought together, forming between them a slit of adjustable width through which the breath passes. The opening between the vocal cords is called the glottis. The flow of the breath is modulated to form the sounds of speech by the vibration of the vocal cords and by the resonant reinforcement of the vocal cavities.

Speech is composed of letter sounds usually divided into vowels and consonants, and those ordinarily used in the English language are tabulated in Fig. 1. So far as possible the sounds are expressed by the letters most commonly used to designate them. In the case of some of the vowels arbitrary markings are employed to distinguish sounds which are different but which are represented by the same letter. The examples given in parentheses will help to interpret the sounds, and it

1—Vowels




2—Combinational and Transitional Vowels, w, y, ou, ī, h

3—Semi Vowels, l, r

4—Stop Consonants

| Voiced | Unvoiced | Nasalized | Formation of Stop |
|---|---|---|---|
| b | p | m | Lip against lip |
| d | t | n | Tongue against teeth |
| j | ch | . . | Tongue against hard palate |
| g | k | ng | Tongue against soft palate |

5—Fricative Consonants

| Voiced | Unvoiced | Formation of Air Outlet |
|---|---|---|
| v | f | Lip to teeth |
| z | s | Teeth to teeth |
| th (then) | th (thin) | Tongue to teeth |
| zh (azure) | sh | Tongue to hard palate |

FIG. 1—CLASSIFICATION OF THE SPEECH SOUNDS

is believed that for most readers the classification will be apprehended more readily with the symbols used than with a system employing entirely different symbols for each sound some of which would necessarily be new and strange. Readers familiar with phonetics will easily be able to express these sounds in the International Phonetic Alphabet or in other systems of phonetic symbols.

The classified letter sounds are thirty-six in number. The vowels and consonants may be classified phonetically into (a) Pure Vowels, (b) Transitional Vowels, (c) Semi-Vowels, (d) Stop Consonants, and (e) Fricative Consonants. Referring to Fig. 1, the triangular diagram at the top of the table represents the first two classes. When a vowel is spoken the vocal cords vibrate in a complicated manner, the characteristics of which are largely determined by the individuality of the speaker. In general, the fundamental or lowest tone of the vibration is rather low in pitch and somewhat lower for men than for women. The mouth and throat cavities, modified by the shape and position of the tongue and lips, act as resonators to reinforce and amplify the relative strength of various harmonics. In this way the shape and position of the mouth and tongue determine largely the particular vowel spoken. The vowel "ū" at the upper left of the triangle is formed by rounding the lips, drawing back the tip of the tongue, and raising it at the back in such a way that the throat is almost closed off and the mouth is formed into a single large resonant cavity. Overtones of the cord vibration in the vicinity of about 300 cycles are strongly reinforced. As we come down the left-hand side of the triangle, pronouncing the sounds indicated, the lip opening widens and the jaw is lowered. The tongue is still raised at the back, and we have single resonance until the bottom point of the triangle is reached. In pronouncing the sounds "a" and "ȧ" the lips are wide open. With the former the jaw is dropped, the tongue is only slightly raised at the back, and the most prominent reinforcement is in the neighborhood of 1000 cycles. With the latter the tongue lies flat in the mouth, and the mouth and throat form connected cavities of nearly equal size. There is double resonance, the two reinforced tones lying in the region from about 800 to 1200 cycles. As the vowels on the right-hand side of the triangle are pronounced starting upward from "a," the separation of the lips becomes smaller, the tongue is raised in the center, and then further forward. These vowels are all characterized by double resonance. With the sound "ē" the lips are drawn to form a wide slit, the tongue is raised in front until its ridge is closely opposite the roof of the front of the mouth. The tongue is drawn forward so that the back of the mouth and the throat form a large resonant chamber. The small tubular space over the tongue at the front leads from the larger space to the exit at the lips. The two frequency regions which are characteristic of the sound "ē" are in the vicinities of 300 and 2500 cycles.

The transition vowels or dipthongs are those formed by passing from one vowel to another. For example, the sound "ī" is pronounced by forming the mouth as if to say "a" and then rapidly passing to the sound "ē". Similarly, the sound designated by the letter "w" is made by forming the mouth as if to say "ū" and then passing suddenly to any of the other pure vowels.

Ordinarily when pronouncing a vowel the glottis opens gently at the beginning of the sound, and the controlled passage of breath produces the sound. If the vocal cords are separated initially in such a way that the glottis is open and the sound is begun by a rather forcible expulsion of breath, the letter "h" is prefixed to the vowel. "l" and "r" partake of some of the characteristics of vowel sounds and are usually classified as semi-vowels.

The stop consonants are those accompanied by the formation of a stop in some part of the mouth. For example, "b," "p" and "m" are all characterized by a stop formed with the two lips. The consonant sound "p" is simply produced by pressing the lips together and then speaking a sound which is begun by having the breath part the lips somewhat forcibly. If the vocal cords are vibrated at the same time the sound "b" is produced. This accompanying vibration of the cords is the characteristic difference between "b" and "p." For the sound "m" the stop is the same and the cords vibrate. The "m" sound is nasal. The lips are pressed together and the breath is released through the nose. The stop at the lips is broken when the sound is terminated or when a succeeding vowel begins. The method of producing the other stop consonants can readily be followed from the table.

The fricative consonants are characterized by the rushing sound of the breath through a characteristic air outlet. We have voiced and unvoiced consonants among the fricative sounds as well as among the stop consonants. For example, the sound "f" is produced by forcing the breath through the air outlet between the upper teeth and the lower lip. The sound "v" is formed in the same way except with the accompaniment of vocal cord vibrations. The method of producing the other fricative consonants is easily seen by reference to Fig. 1.

The speech sounds thus produced in the course of conversation are radiated from the speaker and transmitted through the air by means of pressure waves. These air vibrations are very tiny and exceedingly complicated. In physical analyses of speech it is usually these pressure waves or their duplicates, converted into electrical vibrations, which are studied. Many of the results here described were obtained with a certain type of high-quality electrical reproducing system or circuit as the basis of the experiments. This system consists of a special form of telephone transmitter, a five-stage vacuum-tube amplifier for magnifying the electric speech currents, and, to terminate the circuit, either a group of telephone receivers of special construction or an experimental type of recording apparatus. The design and construction of this experimental system is such that it is probably the most nearly perfect telephonic reproducing apparatus so far built. Its quality is indistinguishable from that of direct air transmission.

In speaking a given letter sound, only the component frequencies of the particular sound (*i. e.*, a sort of "acoustic line spectrum") are being emitted. By impressing a steady sound on the reproducing system mentioned above and by rapidly inserting in succession suitable sharply-resonant filters covering the range of interest, harmonic analyses of the sustained tone may be made. Fig. 2 shows the amplitude-frequency characteristics of some of the English vowels obtained in this way. While these results are typical, it is to be noted that they represent the vowel sounds as pronounced by one particular speaker.

But different speech sounds have different components, and moreover the same sound is frequently pronounced at different pitches, since conversational

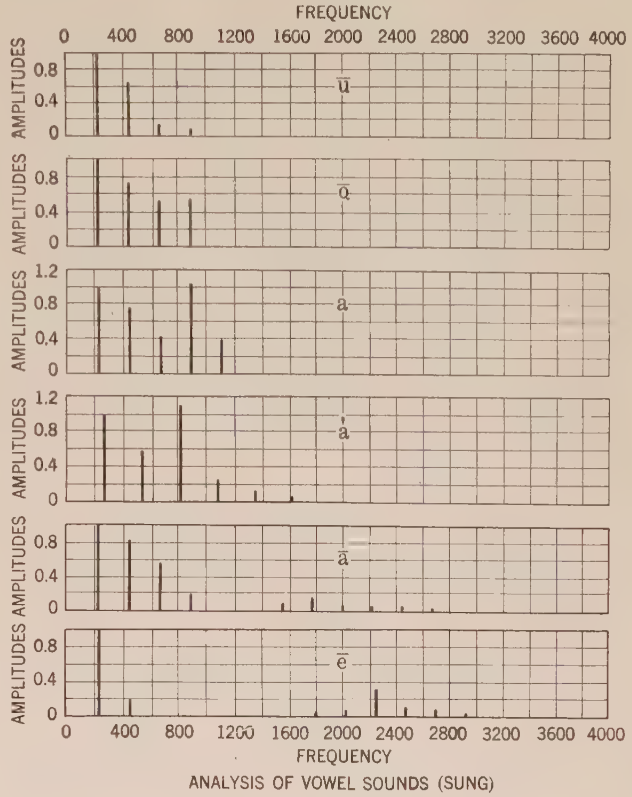



Fig. 2—Amplitude-Frequency Data of some English Vowels

speech has more or less melody to it. In the aggregate speech it may be taken to be represented by a band spectrum. Fig. 3 represents the "acoustic spectrum" of English as obtained from a large number of observations with six different speakers.

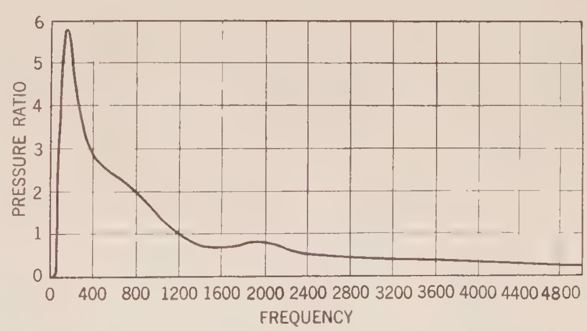



Fig. 3—"Acoustic Spectrum" of English

Speech energy extends from a frequency of 60 cycles to above 6000, with a maximum at about 200 cycles. The vowel sounds carry most of the energy of speech and their important frequencies lie below 3000 cycles. The consonants are the characteristic quips and quirks

with which the syllables begin and end. They are weak in energy, but very important to good intelligibility. In general, they are rather high in frequency, some of them involving vibrations going up to a frequency of 6000 cycles or even higher. The speech energy output of the normal voice has been found to be at the rate of about 125 ergs per second.

In other terms, simple computation shows that if we could have a million persons talking steadily and convert the energy of the voice vibrations into heat, they would have to talk for an hour and a half to produce enough heat to make a cup of tea. This merely serves to illustrate that in terms of power or energy human speech is exceedingly weak. Furthermore, most of this energy is carried by the vowel sounds. On the other hand, the consonants, as will be shown, are more important to perception and interpretation by the ear, so that energy per se is not so much the primary requirements of speech reproduction, but rather its distribution, and particularly its distribution among the higher frequencies.

The human hearing mechanism is usually considered to have three parts. The outer ear includes the lobe, the ear canal, and the drum. The middle ear is a small hollow space containing the chain of small bones (malleus, incus, and stapes) which comprise the mechanical transmission chain for carrying sound vibrations from the ear drum to a small annular membrane, the fenestra ovalis or oval window. The middle ear also contains the muscles which condition the drum and transmission chain so as to accommodate the mechanism to hearing under the variety of actual conditions.

The inner ear is a spiral space in the bony shell called the cochlea. This space is filled with fluid. It is separated into two compartments by the narrow flexible basilar membrane except at the apex of the cochlea where a tiny passage, the helicotrema, connects the two compartments. At the base of the cochlea there is a membraneous diaphragm, commonly called the round window, located on the other side of the basilar membrane from the oval window. Within the spiral casing and terminating on the dividing membrane is the multitude of terminals which connect with the hearing center of the brain through the auditory nerve.

Sound vibrations are transmitted by the stapes through the oval window to the inner ear. At ordinary frequencies vibrations are transmitted through the fluid to a proper distance along the basilar membrane (the appropriate position depending upon the frequency) where they are passed through the membrane and sensed. The excess of vibratory energy transmitted to the second compartment is relieved by the flexibility of the round window. The pitch of a simple tone depends upon the position of maximum response of the basilar membrane—high tones near the base, low tones near the apex of the cochlea. The brain is believed to detect the pitch by its experience in associating tones of different pitches with the stimulation of different nerve groups. When the pitch of the tone is very low, the fluid is moved back and forth around the basilar membrane through the helicotrema. Such impulses follow each other so slowly that the stimulation of the nerve fibers thereby produced is not of the type commonly recognized as a sound sensation. If the pitch of the tone is sufficiently high, the vibratory impedance of the ear mechanism is such that little or no energy is communicated to the inner ear, and in that event also the nerve terminals are unaffected.

The transmission efficiency of the mechanical system linking the ear drum with the basilar membrane is not equal at all frequencies, and its operation varies also with the intensity or loudness of tone. Changes of intensity are probably detected either by change in the amount of agitation of the nerve terminals or by bringing into play wider zones of nerve terminals in the vicinity of the greatest vibration. The marvelous delicacy of the ear mechanism is called to attention when one considers that, in the average case, the basilar membrane by means of which all of these various tones are sensed is only a little over an inch long.

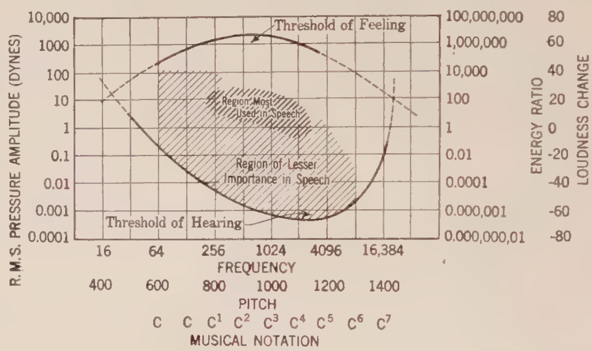



Fig. 4—Area of Audition

Fig. 4 is a plot of auditory sensation for the average human ear. The lower curve shows the sensitiveness of the ear for sounds of different pitches and is called the threshold of hearing. The data were taken by measuring the least sound which could just be heard at each of a number of frequencies. The sensitivity is measured in terms of the minimum audible sound pressure while the frequencies are arranged according to musical intervals (logarithmic scale). The upper curve shows the extreme values of loudness at which the ear begins to experience the sensations of feeling the vibrations. This is the threshold of feeling and may be considered practically as a maximum audibility curve. Sounds much louder than these are painful. The two curves enclose the area of audition. The data have been extrapolated at high and low frequencies to the points of intersection, the extrapolation being guided to a certain extent by other available information. At frequencies in the neighborhood of sixty cycles a high intensity is felt as a sort of flutter. As

the frequency is lowered still further to the point where the hearing and feeling lines appear to intersect, it is difficult to distinguish between the two sensations. For frequencies lower than this it is easier to feel than to hear the air vibration. A similar intersection of the two curves occurs at a very high frequency. This appears to give a logical basis for defining the frequency limits of hearing, and as seen from the plot they are about 20 and 20,000 cycles respectively for persons of average hearing. At the lower and upper limits of audition it takes about a hundred million times as much energy to enable one to hear as it does in the range of 1000 to 5000 cycles where the ear is most sensitive. At all frequencies the energy required is small, and in the most favorable region the minimum audible tone corresponds to a pressure change per square centimeter of about 0.001 of a dyne. This pressure is roughly equivalent to the weight of a section of a human hair about one thousandth of an inch long (about one-third as long as its diameter).

In the portion of the audible region most commonly used, it is found that the smallest change in the intensity of a tone which is just discernible, is equal to about one-tenth of its original value. In other words, in general the law connecting loudness discrimination with the energy of the tone is a simple logarithmic one. It has been proposed that change in loudness sensation be measured in units such that a loudness change is equal to ten times the common logarithm of the ratio of the energies.

It has been found that the law of pitch sensibility is approximately logarithmic also. The fractional change in frequency which is just perceptible is equal to about three-thousandths over the greater part of the ordinary musical range. The ear perceives octaves as somewhat similar sounds. With these and other facts of hearing in mind, it has been proposed to measure pitch sensation on a scale such that the pitch of tone will be given by one hundred times the logarithm to the base two of the pitch number or frequency. These sensation scales of loudness and pitch are given on Fig. 4 in addition to the physical scales or energy and frequency. From the observations made on intensity and pitch discrimination, it is possible to show that approximately three hundred thousand different pure tones are separately distinguishable by the average ear. The number of complex sounds which can be sensed is even much greater.

The non-linearity of operation of the ear gives rise to a number of interesting hearing phenomena. When a simple tone is made very intense the vibratory efficiency of the middle ear and cochlea are no longer constant. This gives rise to harmonics which cause the basilar membrane to vibrate in other zones than that characteristic of the fundamental. If a second intense tone of another pitch is now impressed, its harmonics are also introduced. Under some conditions combination tones appear having frequencies which are the sums or differences of the fundamentals or harmonics. Some of the combination tones may take the form of beats. Such harmonics, combination tones, and beats are purely subjective effects brought in by the departure from linearity of the vibratory mechanism of the internal ear.

The masking of one tone by another is a second effect of interest. An intense low tone is observed to mask or obscure weaker, high tones; but high tones, even though intense, have scarcely any masking effect on lower ones. The explanation offered for this is that the intense low tone, with its subjective harmonics, sets up vibrations in the basilar membrane which extend along the membrane to a considerable distance from the base of the cochlea so that vibrations of higher frequencies which might otherwise obtain in the adjacent region, are interfered with. With the opposite state of affairs, the high-pitched vibrations extend only a short distance from the base, and more remote portions of the membrane are free to sense tones of lower pitch.

It will readily be apprehended that with complex tones complicated effects may be obtained. When such a tone is made very loud, as by amplification, its tone quality may be greatly altered even though its composition is in nowise changed. In general its low frequency components will appear more prominent and its higher frequencies diminished.

Referring again to Fig. 4, the area of sensation most used in conversation is represented approximately by the shaded area of the figure. The more intense vowel-like sounds account for the upper part of the shaded region, while the weaker consonants account for the most part for the shaded regions of lower intensity and higher frequency. It is evident that the processes of evolution have worked out in such a way that conversation usually employs the central part of the area of audition. For clear understanding the weaker consonant sounds must not fall below the threshold of hearing nor must the loudest speech sounds rise to such intensity that the threshold of feeling is reached or non-linear effects introduced.

Defective hearing is lacking more or less in range of sensation, (that is either frequency or intensity), quality of sensation in various parts of the sensation area, or in the binaural sense or the ability to locate the direction from which a sound is received. While space will not permit a discussion of abnormal hearing, Fig. 5 is presented to illustrate the way in which defective range of sensation may be measured and compared with normal conditions. The area of audition plot is again reproduced together with hearing-threshold curves, or audiograms, for a person whose hearing is subnormal due to catarrhal deafness. The areas between these threshold-of-hearing curves and the threshold of feeling are the diminished areas of sensation for the respective ears. The scales used in plotting the area of audition are such that the area of

any part of the diagram represents approximately the number of simple tones which can be distinguished in that region. Hence, the proportional part of the whole area in which sensation can still be perceived may be taken as a measure of deafness. It is apparent that the subject retains about fifty per cent of the normal range in this case. He hears and interprets conversation with some difficulty. A suitable deaf set amplifying the speech region to the position indicated by the dashed lines would be of some assistance. Certain of

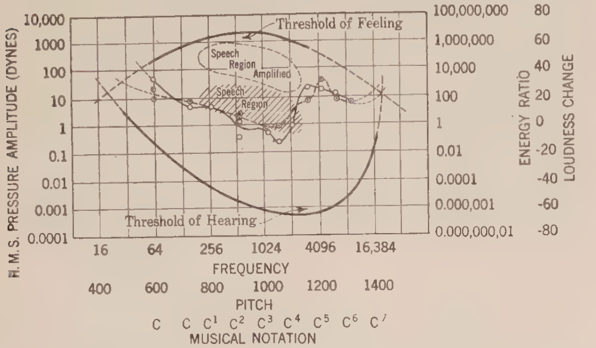



Fig. 5—Normal Area of Audition with Audiograms of a Deaf Person

the weaker consonant sounds would frequently be low enough in intensity to drop below the range of his hearing even with this aid, however. If too great amplification were provided, the energy of some of the vowel sounds would give rise to subjective distortion and might even produce painful sensations. It is of interest to note that an unusual degree of non-linearity is characteristic of some types of defective hearing. It is evident that in prescribing aids for the deaf, great care must be exercised in order that there may be no danger of injury and in order that the best results may be obtained.

For the study of the interpretation of speech it is necessary to be able to adjust at will the loudness of the speech sounds and to introduce determinable amounts of distortion. With acoustic apparatus this is very difficult and consequently for many years meager results were obtained. The recent development of the vacuum tube and the electric-wave filter make it possible to produce the equivalent of the desired changes in the high-quality reproducing system mentioned above. By means of distortionless controls operating on the amplifier the loudness of the reproduced speech is varied through a very wide range. By inserting electric-wave filters in the circuit the speech waves can be distorted in known ways. For example a low pass filter suppressing frequencies above 1000 cycles is connected in circuit and articulation tests made to find the intelligibility carried by frequencies between 0 and 1000 cycles. For experimental purposes it is practicable to construct such filters in which the suppressed frequencies are diminished to one-millionth or less of the values which would otherwise obtain, while the passed frequencies are scarcely affected. Similarly high-pass filters can be made which suppress all frequencies up to a certain marginal region and pass those above it. Such filter structures are made by the proper combination of suitable inductance coils and condensers.

Studies of interpretation further require an experimental method for measuring the ability of the ear to understand transmitted speech sounds with different conditions of loudness and distortion. The method developed consists in pronouncing detached speech sounds into the transmitting end of the experimental system and in having observers at the receiving end write the sounds which they hear. Comparison of the observed sounds with those called shows the number and kind of errors made. The per cent of the total sounds spoken which are correctly received is called the articulation of the system. For these tests simple syllables are used constructed in a systematic manner from the 36 fundamental speech sounds and arranged in lists of 50 syllables each. A carefully worked out technique is observed in the testing.

Articulation tests have been made upon the high-quality experimental system without distortion, but with controls adjusted to give various intensities of output from the threshold of audibility to values considerably above the level of ordinary conversation. The results obtained are shown in Fig. 6. The abscissas of the curve represent loudness and are expressed as the ratios by which the speech energy has been decreased from the initial intensity at exit from the mouth. When the volume is reduced to about one ten-billionth of the initial speech intensity, the articulation be-

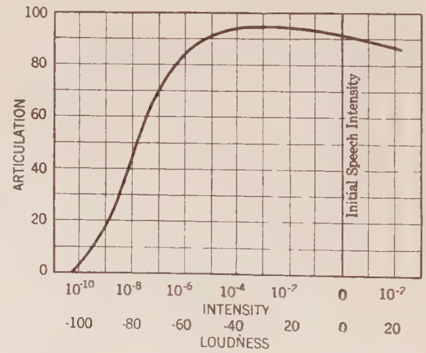



Fig. 6—Articulation-Loudness Characteristic for Speech

comes zero. This point corresponds to the value at which speech becomes inaudible. At about one thousandth of the initial speech intensity, the articulation becomes a maximum. With louder speech than this perception is less accurate, probably due to overloading of the ear mechanism and subjective distortion. These results were obtained in a perfectly quiet room. When the observer is submerged in an atmosphere of noise the speech must be louder in order to get the best hearing conditions.

The articulation data have been further analyzed in such a way as to show the errors made at various intensities for each of the fundamental sounds. The results for some typical sounds are shown in Fig. 7.

It is observed that in general diphthongs and vowels are more easily heard than consonants, and that of the latter the stop consonants are heard with fewer mistakes than are the fricative ones. If all the sounds are listed in order of average articulation the top quarter will contain no consonants and the lower half no vowels. When speech becomes weak, the errors of the consonants increase greatly, their articulation values falling off at higher intensities than is the case with the vowels.

There are some exceptions to these general statements. At moderate volume the short vowel e is near the bottom of the list, but at very weak volume 22 sounds are harder to perceive. l, r, and ng are all more readily heard than e at moderate volume, but when very weak they fall below it. l, which ranks with the diphthong ī, as one of the easiest sounds at moderate volume, is mistaken about two times out of three when very weak.

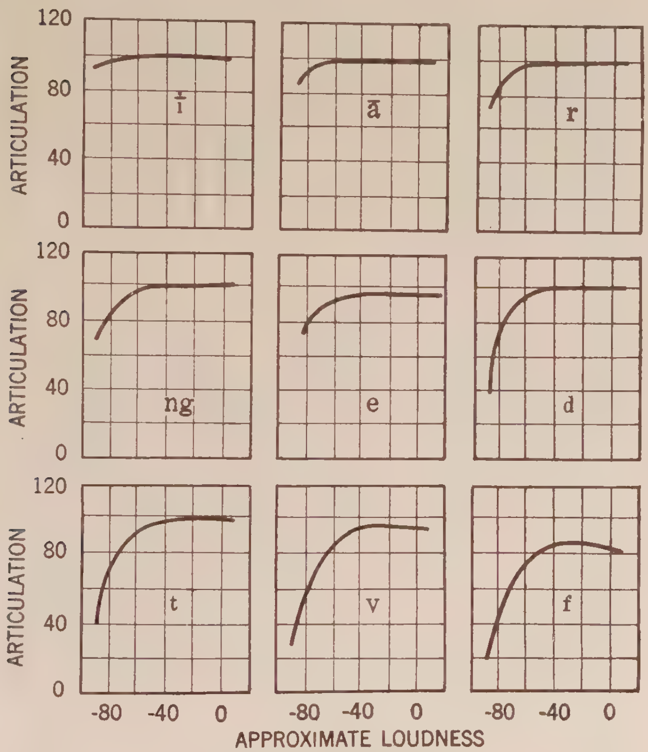



Fig. 7—Articulation-Loudness Curves for some Typical Speech Sounds

The diphthongs ī, ou, and the long vowels, ó, ō, ā, all have average articulations better than 95 and even when very weak have values of 84 or better. On the whole the sounds th, f, s, and v are hardest to hear correctly, and they account for more than half of all the errors of interpretation. In general, it is observed that the volume at which errors begin to be large is different for different sounds and is usually higher for the consonants than for the vowels. Within the precision of the data, the intersections on the axis of abscissas all correspond with the threshold of hearing.

The effect of frequency distortion has been investigated by inserting several systems of electric wave filters in the high-quality experimental circuit. Articulation results with low-pass and high-pass filters are shown in Fig. 8. The ordinates show the per cent of syllables called which were correctly recorded at the receiving end. The abscissas represent the marginal or cut-off frequency of the filter. Looking at the curve for the low-pass filter, marked Articulation L, the point (1000, 40) indicates that an articulation of forty per cent is obtained when the system transmits only frequencies up to 1000 cycles. Looking at the curve for the high-pass filters, marked Articulation H, the point (1000, 86) indicates an articulation of eighty-six per cent for a system transmitting only frequencies above 1000 cycles. The dotted curves show the per cent of the total energy in speech transmitted through filters of the two types having cut-off frequencies corresponding to the abscissas. Sixty per cent is lost

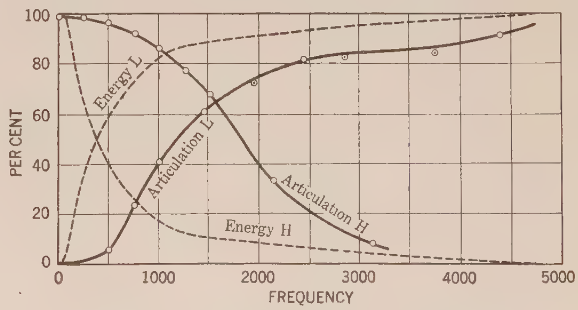



Fig. 8—Articulation-Distortion Characteristics for Speech

if all the energy below 500 cycles is eliminated, but only two per cent of the articulation. The suppression of the frequencies above 1500 cycles reduces the articulation by 35 per cent but only 10 per cent of the energy lies in this region. The suppression of all frequencies below 1000 cycles has no greater effect than the suppression of the frequencies above 3000 cycles. This is quite contrary to the popular notion of the characteristics of speech. The mean frequency from the standpoint of articulation is about 1550 cycles. An articulation of sixty-five per cent is obtained when either the frequencies below or those above that point are used. The speech quality sounds very different in the two cases, however, in the one being low and dull, and in the other high and shrill.

It should be borne in mind that naturalness of reproduction, as well as articulation, is an important element of understandable and satisfactory spoken communication. As has been pointed out above, although the fundamental cord tones and harmonics lying below 500 cycles carry most of the speech energy, they contribute little to the articulation. It has been observed that naturalness of reproduction is greatly

affected depending upon whether or not these low-frequency tones are preserved. While it might be concluded from the articulation data then, that frequencies in the lower part of the speech range are unimportant, a fuller consideration justly attributes an added measure of importance on account of naturalness. The naturalness of speech quality is a characteristic calling for considerable further investigation.

The curves of Fig. 9 show the articulation of some typical speech sounds when the frequency regions below or above the given point are suppressed. The ordinate gives the number of times the sound was correctly observed per 100 times called; the abscissa, the frequency of cut-off. In each figure the effect of suppressing the frequencies below the cut-off is shown by the curve at the left, the effect of suppressing those above it by the one at the right. The diphthong ī, the long vowel ē, and the semi-vowel l are each perceived with an error less than three per cent when either half of the frequency range is used. The intersections of

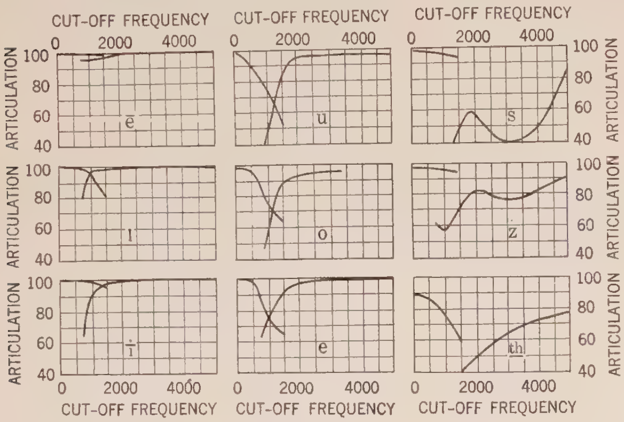



FIG. 9—ARTICULATION DISTORTION CHARACTERISTICS FOR SOME TYPICAL SPEECH SOUNDS

the two curves, the cut-off frequency where the articulation is the same with either low-pass or high-pass filters, are at different points in each of the three cases, however.

In the cases of the short vowels u, o, and e, the frequencies below 1000 cycles are important to good articulation, but those above 2000 may be suppressed with little effect.

In the cases of the fricatives s, z, and th, quite different effects are observed than with the former two classes. Some of the peculiar results shown have not yet been explained. Even if all frequencies up to 5000 cycles are correctly transmitted, these sounds are noticeably impaired by the suppression of those above. The lower frequencies up to 1500 cycles contribute practically nothing to the articulation of s and z. It has been observed, in the case of a system which suppresses all frequencies above 2500 cycles, that about 82 per cent of the syllables were heard correctly in an articulation test, and that the errors were made up principally of failures in the three sounds s, z, and th.

In conclusion then, we have seen that the ordinary ear is an exquisitely developed organ for sensing minute and rapidly repeated variations in air pressure. It can perceive sound waves ranging in pressure amplitude from less than 0.001 dyne to over 1000 dynes, and in frequency of vibration from about 20 cycles per second to about 20,000—a range of about ten octaves. Human speech employs frequencies from a little below 100 cycles per second to above 6000 cycles, a range of about six octaves. The intensities and frequencies used most in conversation are those located in the central part of the area of audition. The energy of speech is carried largely by frequencies below 1000, but the characteristics which make it intelligible, largely by frequencies above 1000. Under quiet conditions good understanding is possible with undistorted speech having an intensity anywhere from one hundred times greater, to a million times less than that at exit from the mouth. On the whole, the sounds th, f, s and v are hardest to hear correctly and they account for over half the mistakes made in interpretation. Failure to perceive them correctly is principally due to their very weak energy although it is also to be noted that they have important components of very high frequency.

These data are of fundamental importance in the art of electrical communication. But they have also a broader interest and utility. The information gleaned by physicists in the study of speech and hearing increases the understanding of phoneticians and physiologists. It will aid public speakers, linguists, and physicians, and help to lighten the burdens of the deaf and dumb. Investigators who engage in the field of human acoustics have many interesting physical problems to solve. Furthermore study of these senses, dealing as it does with two of the primary tools of the human race, is work of extraordinary appeal holding forth promise of direct service to mankind.

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# Experimental Analysis of Stability and Power Limitations

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***Review of the Subject:***—*A method of determining the power limit of a transmission system taking into account the characteristics of the synchronous condensers and load in conjunction with those of the transmission line is described. The power limit of a transmission system divided into two sections by an intermediate synchronous condenser station is determined and compared that of the same system without the condenser station at the mid-point. The theory was checked by shop tests on an artificial transmission system of sufficient capacity so that accurate results could be obtained. Tests were also made on voltage stability, hunting and the effect of short circuits causing the system to pull out of synchronism.*

## Introduction

Due to the rapid growth in the use of electrical energy economic conditions have made it necessary to consider the transmission of large blocks of power over great distances. Theoretical investigations of these transmission problems have indicated that there is a definite limit to the amount of power which can be transmitted over a given line.

On high-voltage transmission lines this limit is determined principally by the reactance, which is large as compared to the resistance, on account of the wide conductor spacing. Previous investigations have mainly considered the limitations of the transmission line alone. In an actual transmission system the nature of the load and the size and characteristics of the synchronous condensers must be taken into account in determining the maximum amount of power which can be transmitted without hunting, loss of synchronism, or voltage instability taking place.

The maximum amount of power which can be transmitted over a given line may be increased by "loading the line" with synchronous condensers at intermediate points. The use of synchronous condensers in this manner was given consideration for the transmission lines from the St. Lawrence and Niagara developments of the Superpower Survey. This subject has been presented before the Institute by F. G. Baum in a paper published in the August, 1921, A. I. E. E. Journal.

The present paper covers an investigation, supplemented by actual tests, of the factors affecting the stability of transmission systems. The tests were made on two artificial "*T*" transmission lines which were built up of resistors, reactors, and static condensers, and operated normally at 2380 volts; power was obtained from a 625-kv-a. generator and two 425-kv-a. synchronous condensers were available, thus permitting the "loaded line" operation to be tested. Standard voltage regulators of the vibrating type were used with the generator and each of the synchronous condensers. The tests were carried out on a large scale so that results comparable with those in actual operation could be obtained.

*Abridgement of paper presented at the A. I. E. E. Midwinter Convention, Philadelphia, Pa., February 4-8, 1924. Complete paper available without charge to members upon request.*

## Determination of the Power Limitations of a Transmission System

*Use of circle diagrams:*

*Power Limit of Transmission Line Alone:*

An actual transmission line with its step-up and step-down transformers is quite a complicated network, since it involves the series impedances and exciting admittances of the transformers in addition to the distributed resistance, inductance, and capacity of the line itself. The characteristics of this complicated network can conveniently be represented by means of circle diagrams since the relation between kilowatts transmitted over a line and reactive kilovolt amperes required to maintain a constant receiver voltage is a circle, provided the supply voltage is constant. An exact method of combining the constants of the line with those of the transformers to obtain the general circuit constants of the entire network is described in the companion paper entitled "Power Limitations of Transmission Systems." From the general circuit constants thus derived the mathematically exact circle diagrams can be obtained. The methods of calculating circle diagrams and their characteristics have been covered in other papers.[1]

The maximum amount of power at various constant receiver voltages which the line (with transformers) *considered by itself* can deliver may be determined from the receiver circle diagrams. The power limit of the entire system, taking into account the characteristics of the apparatus connected to the line will, in general, be less than the power limit of the line alone.

*Power Limit of Entire System:*

*Stability of Receiver Voltage:*

The necessity for considering the characteristics of the synchronous condensers and load as well as the

1. R. A. Philip, Economic Limitations to Aggregation of Power Systems, 1911, A. I. E. E.
H. B. Dwight's book on "Constant Voltage Transmission."
R. D. Evans & H. K. Sels, *Elec. Journal* for July, August, December 1921 and February 1922.

characteristics of the line in determining the maximum amount of power which a system can deliver has already been pointed out. The power limitations and stability of the receiver voltage are so closely related that it is best to consider them at the same time. When a constant amount of power is being delivered at the receiver the usual conception is that an increase in lagging kv-a. drawn over the line will decrease the receiver voltage, or conversely, an increase in leading

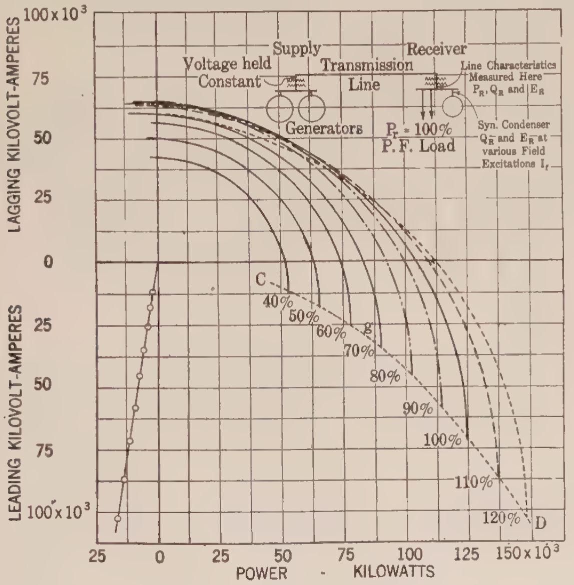


Fig. 4—Receiver Circles

500-mile transmission line with stepdown transformers; 750,000 cir. mil copper, 19 ft. equivalent spacing; 90,000 kv-a. transformer bank; supply voltage constant at 220 kv.; receiver voltages expressed in per cent of 220 kv.

kv-a. will increase the receiver voltage. On most transmission lines this is not true beyond a certain load.

Fig. 4 shows the receiver circle diagrams for a 500-mile transmission line with stepdown transformers included as a part of the line. The voltage has been assumed to be held constant at 220 kv. at the high-tension side of the step-up transformers. The various circles show the relations between kilowatts and reactive kv-a. for different voltages at the receiver end expressed as a percentage of 220 kv.

It is apparent that, with a constant kilowatt load being transmitted, the receiver voltage (with constant supply voltage) depends on the reactive kv-a. drawn over the line. The curves drawn in full on Fig. 5 show this relation at a number of different kilowatt loads. These curves were derived from Fig. 4 by taking cross-sections perpendicular to the kilowatt axis.

From Fig. 5 it may be noted that at a constant load of 100,000 kw. an *increase* in the lagging kv-a., or what amounts to the same thing, a *decrease* in the leading kv-a. drawn over the line, will actually *raise* the receiver voltage. When delivering 50,000 kw. at 100 per cent voltage 50,000 lagging kv-a. are required. At this point with the lagging kv-a. *remaining very nearly constant* at 50,000 kv-a. a variation of the receiver voltage from 94 per cent to 102 per cent could take place. If voltage instability occurred at this point as might be expected from a cursory consideration of the synchronous condenser characteristics, only 50,000 kw. could be delivered over the line. Actually there will be no difficulty in operating at this point because with other factors such as the excitation of the synchronous condensers remaining constant the fluctuation in voltage is always accompanied by a variation in reactive kv-a., and this variation tends to prevent the change in voltage.

The point at which voltage instability will occur may be determined by plotting the variation in receiver voltage with a change in synchronous condenser excitation at different kilowatt loads. The fundamental condition for successful voltage regulator operation is that an increase in the condenser field excitation should always be accompanied by an increase in the receiver voltage, or conversely a decrease in excitation should lower the voltage.

In investigating the relation between receiver voltage and condenser excitation a load whose kilowatts remain constant and at 100 per cent power factor independent of the voltage will be used for convenience. Synchro-

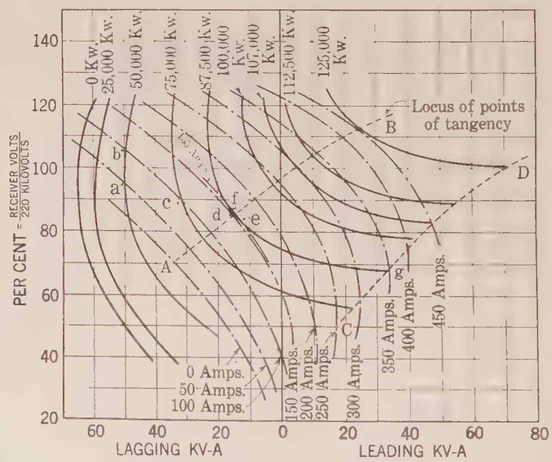


Fig. 5—Transmission Line and Synchronous Condenser Characteristics

500-mile line with stepdown transformers and two 17,000-kv-a. lead and 30,000 kv-a. lag synchronous condensers.

——— Curves show variation in receiver voltage with reactive kv-a. at the receiver for constant kw. loads. Curves obtained from Fig. 4. Load is 100 per cent power factor at all voltages.

—·—·— Curves show variation in synchronous condenser voltage with reactive kv-a. for constant field currents. The condenser voltage and the receiver voltage of the line are identical.

nous motor load simulates such a load in that the kilowatts are independent of the voltage since the load remains constant as long as the frequency (speed) does not change. The power factor will of course vary with the voltage provided the field excitation is constant. The hypothetical 100 per cent power factor load is only used for convenience and modifications to take care of practical cases can be introduced after the theory is developed.[2]

2. Due to lack of space these modifications are not covered in this abridgement of the paper.

Since the load power factor is always constant at 100 per cent all of the reactive kv-a. required to maintain the line voltage comes from the synchronous condenser. Referring to the sketch on Fig. 4, when constant voltage is maintained at the supply end of the line the conditions at the receiver end of the line are completely determined provided the following quantities are known:

$P_R$—The kw. transmitted over the line.

$E_R$—The receiver voltage.

$Q_R$—The reactive kv-a. drawn over the line to maintain the voltage.

Likewise the synchronous condenser point of operation is determined by the following variables:

$I_F$—The field current.

$E_R$—The terminal voltage.

$Q_R$—The reactive kv-a. supplied by the condenser.

The reactive kv-a. drawn over the line and the reactive kv-a. delivered by the condenser are equal since the load has been assumed to remain at 100 per cent power factor. The terminal voltage of the condenser is also identical with the receiver voltage of the line. This suggests plotting for the line a family of curves showing the variation in receiver voltage with reactive kv-a. at a number of kilowatt loads and superposing on them another family of curves which show the terminal voltage of the synchronous condenser plotted against the reactive kv-a. delivered by the condenser at a number of different field currents. The chain dotted curves in Fig. 5 are for two synchronous condensers operating in parallel, each having a rating at 100 per cent voltage of approximately 30,000 kv-a. lagging at the minimum excitation and 17,000 kv-a. leading at the maximum excitation.

Starting at point *c* Fig. 5 and *keeping the load constant at 75,000 kw.* the voltage will rise from 90 per cent to 104 per cent if the excitation is increased from 100 amperes to 150 amperes. It should be noted particularly that the lagging kv-a. has been increased from 31,500 kv-a. to 34,400 kv-a., that is, an increase in the lagging kv-a. drawn over the line actually increased the receiver voltage. By keeping the load constant and increasing the excitation to 250 amperes the voltage will rise to 122 per cent. In Table A the variation in receiver voltage and reactive kv-a. drawn over the line as the synchronous condenser excitation is changed from 100 to 250 amperes with a constant load of 75,000 kw. is tabulated from the points taken on the 75,000 kw. curve.

TABLE A

| Kw. Load | Syn. Cond. Field Amps. | *Receiver Voltage | Lagging Kv-a. | Lagging Current |
|---|---|---|---|---|
| 75,000 | 100 | 90% | 31,500 | 91.6 amps. |
| 75,000 | 150 | 104% | 34,400 | 86.5 " |
| 75,000 | 200 | 114.5% | 34,400 | 78.0 " |
| 75,000 | 250 | 122% | 33,300 | 71.6 " |

*100 per cent voltage = 220 kv.

The lagging component of current drawn over the line, which was calculated from the receiver voltage and lagging kv-a. at the different points, is also tabulated. By increasing the receiver voltage from 90 per cent to 104 per cent, the lagging kv-a. drawn over the line is increased from 31,500 to 34,400 kv-a. while the lagging current drawn over the line decreased from 91.6 amperes to 86.5 amperes. The decrease in lagging current drawn over the line as the synchronous condenser excitation is increased accounts for the rise in line voltage even though the lagging kv-a. goes up. The lagging kv-a. increased because the line voltage is going up faster than the lagging current is going down.

Assume that the load is constant at 87,500 kw. and the condenser field excitation is 200 amperes, thus giving a receiver voltage of 105.5 per cent. If the power remains constant and the field excitation of the condenser is gradually decreased to 155 amperes point *d* will be reached and the voltage will be 85.5 per cent. At this point the line and synchronous condenser characteristic curves are tangent, and the voltage will be unstable because, with a constant condenser excitation of 155 amperes and a practically constant load of 87,500 kw. the voltage and the reactive kv-a. would fluctuate in the region from *e* to *f*.

*If* it were possible to get beyond the point of tangency between the two families of curves an increase in synchronous condenser excitation would actually decrease the receiver voltage, for example, an increase in the excitation from 155 to 200 amperes would reduce the voltage from 84.5 per cent to 73.5 per cent, with the load remaining constant at 87,500 kw. A still further increase in the excitation to 350 amperes would reduce the receiver voltage to 68 per cent as is indicated at point *g*, which corresponds to the pull-out point of the line alone for 68 per cent voltage. By referring to Fig. 4 it can be seen that point *g* corresponds to the maximum power point of the 68 per cent voltage circle.

If a voltage regulator set to maintain 85.5 per cent receiver voltage at all loads were in use, the regulator would operate satisfactorily at all loads up to 87,500 kw. At loads higher than this with the voltage maintained at 85.5 per cent an increase in condenser excitation would decrease the voltage, which in turn would cause the regulator to still further increase the excitation and the action would be cumulative until the voltage dropped sufficiently for pull-out to occur.

It is even impossible in practise to get beyond point *d* with hand operation of the synchronous condenser field because, in order to get below *d* (the load remaining constant at 87,500 kw.), when starting with 100 per cent voltage, the synchronous condenser excitation must be decreased to 155 amperes and then increased. If the rheostat steps were such that the field current would be reduced to slightly less than 155 amperes, for example to 150 amperes, pull-out of the synchronous condenser and load would take place

because the synchronous condenser with 150 amperes excitation can not deliver sufficient reactive kv-a. required for the transmission of 87,500 kw. at any voltage.

This discussion has dealt with the pull-out point and regulation limit of the entire system for a receiver voltage of 85.5 per cent. At a higher receiver voltage more power could be transmitted without this point being reached. The line *A B* (Fig. 5) is the locus of points of tangency between the family of line characteristic curves and synchronous condenser characteristic curves, and is, therefore, the locus of pull-out points of the entire system for different receiver voltages.

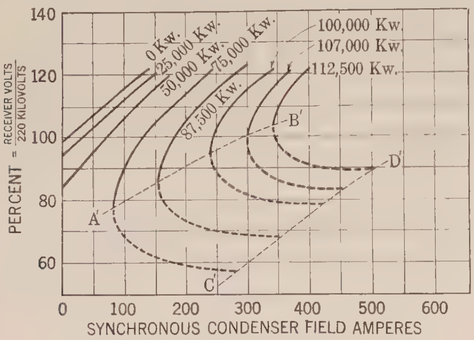


Fig. 6

These curves were obtained from Fig. 5. Curve *A′ B′* is the locus of points at which voltage instability and pull out will occur. It corresponds to *A* – *B* on Fig. 5. Curve *C′ D′* is the locus of the maximum power points of the line alone as determined from the various receiver voltage circles. Corresponds to *C* – *D* on Figs. 4 and 5.

When operating *with 100 per cent receiver voltage* 107,000 kw. is the maximum power that can be transmitted because the 107,000 kw. curve becomes tangent to the 300 ampere excitation curve of the synchronous condenser. In actual operation pull-out could be expected to occur slightly before this point of tangency. For example, when operating at 100,000 kw., if the load suddenly increased to 107,000 kw., the voltage regulator would not have time to make a corresponding increase in the excitation. This gives the effect of an increase in load at a constant field excitation so that the voltage would drop down enough to reach the point of tangency and cause pull-out to take place before the regulator had time to get into action.

Fig. 5 shows the change in the reactive kv-a. during the regulating operation, and Fig. 6, which is derived therefrom by eliminating the reactive kv-a., shows the variation in receiver voltage with condenser excitation at a number of constant kilowatt loads. The line *A′* – *B′* in Fig. 6 corresponds to the line *A B* on Fig. 5 where voltage instability and pull-out of the system occur. The dotted portions of the curve cover the range between the lines *A B* and *C D* in Fig. 5 where an increase in excitation would decrease the receiver voltage, provided it were possible to operate in this range.

The transmission line and synchronous condenser characteristic curves for a 250-mile line controlled by two synchronous condensers having a total capacity of 50,000 kv-a. leading and 21,000 kv-a. lagging at 100 per cent voltage have been illustrated. These curves are based on a hypothetical load which remains constant at 100 per cent power factor independent of the voltage. The locus of the points of tangency between the two families of curves is shown by the dotted line *A B* and was obtained in the same manner as for the 500-mile transmission line previously investigated.

With the voltage maintained constant at 100 per cent the maximum load that can be drawn over the line is 140,000 kw. because the maximum synchronous condenser excitation is reached at this load. Pull-out will not occur at this point, but additional load can only be drawn over the line by leaving the condenser excitation constant at 400 amperes and allowing the voltage to drop as the load is increased. When the load reaches 155,000 kw. the voltage will be reduced to 89 per cent which corresponds to the point of tangency between the two families of curves and the system will pull-out of synchronism.

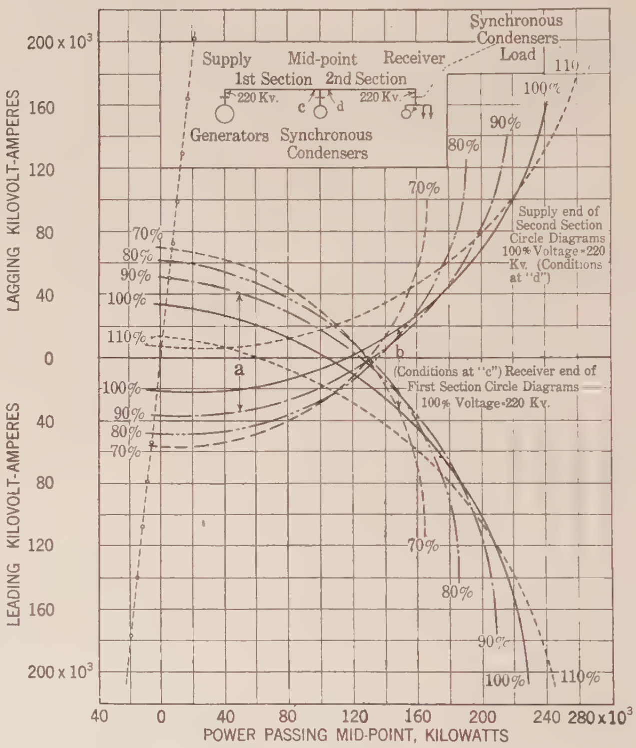


Fig. 7—Mid-Point of 500-Mile Line

220 kv. maintained at supply end of first section and receiver end of second section.

*Power Limit of Loaded Line:*

By "loading" the 500-mile transmission line covered by Fig. 4 with synchronous condensers at the mid-point the maximum amount of power which can be delivered to the receiver end will be increased. The sketch shown on Fig. 7 gives the schematic diagram of the system. By installing synchronous condensers at the mid-point the 500-mile line is divided into 250-mile sections.

A method of obtaining the reactive kilovolt amperes which the synchronous condenser at the middle of the line must deliver under various load and voltage conditions is shown by Fig. 7. By taking a sufficient number of points after the manner indicated at *a* and *b* the characteristic curves for the middle of the line which are shown in full lines on Fig. 8 may be obtained. The characteristics of two 30,000 kv-a. leading and 20,000 kv-a. lagging capacity synchronous condensers are shown by the chain dotted curves.

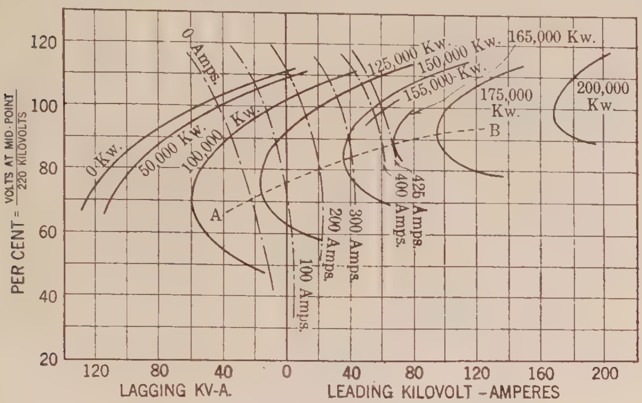


Fig. 8—Mid-Point of 500-Mile Line

Constant voltage = 220 kv. maintained at each end of the line.

——— Curves show relation between volts at mid-point and reactive kv-a. which must be supplied by the mid-point synchronous condenser for different amounts of power passing the center of the line. Obtained from Fig. 7.

—·— Curves show relation between synchronous condenser voltage and reactive kv-a. delivered (at high voltage side of transformer bank) for different values of field current.

Curve *A B* is locus of points of tangency between line and synchronous condenser curves. It is impossible to operate below *A B*.

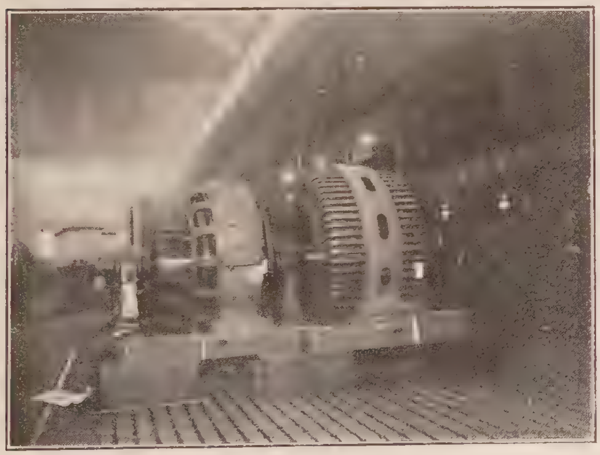

Fig. 9—Motor-Generator Set used as a Source of Power

The line *A B* (Fig. 8) is drawn through the points of tangency between the two families of curves and is the locus of points at which voltage instability and pull-out of the synchronous condenser at the mid-point will occur.

With 100 per cent voltage maintained at the mid-point the limit of the synchronous condenser excitation is reached at 155,000 kw. corresponding to 425 amperes of excitation. The pull-out will not occur at this point and load may be increased to 165,000 kw. by keeping the field current constant at 425 amperes and allowing the voltage at the middle of the line to drop. At 165,000 kw. the voltage at the mid-point will have


Figs. 10-11—Showing the Two *T* Transmission Lines Constructed of Resistors, Reactors and Static Condensers

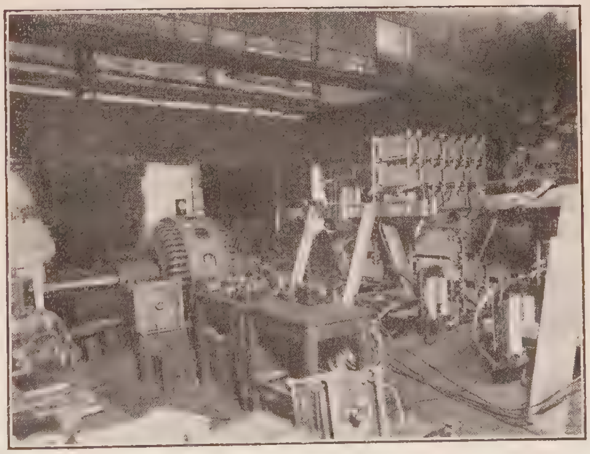

Fig. 12a—One of the Two 425 kv-a. Synchronous Condensers with its Belted Exciter

dropped to 89 per cent at which the line and condenser curves become tangent and voltage instability and pull-out will occur. The load at the receiver end of the 500-mile line at the time of pull-out is 152,000 kw. as

obtained by subtracting the losses in the second section from the load of 165,000 kw. at the middle of the line.

Loading the 500-mile line with 60,000 kv-a. in synchronous condensers at the mid-point, therefore, increased the power limit of the system from 107,000 kw. to 152,000 kw. an increase of 42 per cent.

From the foregoing it may be noted that the power limit of the loaded line is to a large extent determined by the characteristics of the synchronous condensers at the mid-point. If a sufficiently large synchronous condenser were used, the power limit of the system would closely approach that of the first section.

## Stability Tests on an Artificial Transmission System

An artificial transmission system on a sufficiently large scale so that results could be obtained comparable with those expected in actual operation was used for making tests on the power limitations, voltage stability, hunting, and effect of short circuits in causing the system to pull out of step.

*Transmission System:*

Two artificial lines of the *T* type constructed of reactance coils, resistance grids, and static condensers were used. The lines were operated normally at 2380 volts. Power was obtained from a 625 kv-a. generator driven by a direct-current motor. Two 425-kv-a. synchronous condensers were available, thus permitting the two transmission lines to be operated either alone

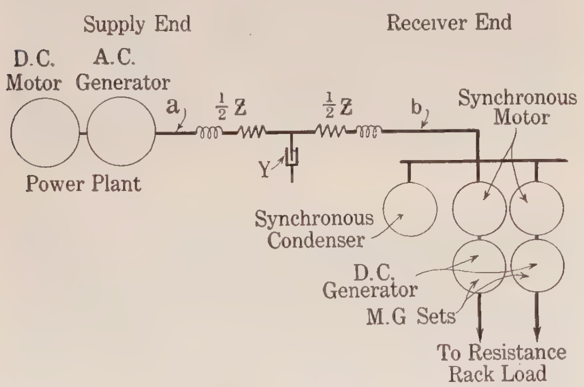


Fig. 13—"T" Transmission Line with Synchronous Motor Load

Line is three-phase.
$Z$ = Impedance to neutral.
$Y$ = Admittance to neutral of static condensers.
Measurements made at "$a$" and "$B$".

as in Fig. 13, or in series with an intermediate condenser station as in Fig. 22 for actually testing a "loaded" line. Voltage regulators for use with the generator and each of the synchronous condensers were provided.

Two 200 kw. synchronous motor-generator sets were used as loads. The direct-current generators of these sets were connected to resistance racks to provide a dead load instead of loading back on the direct-current shop system. The fields of the direct-current generators were separately excited so that the load could be varied gradually by raising or lowering the d-c. voltage.

The resistance grids were arranged so that the amount of the resistance in the circuits could be varied. The static condensers used with each transmission line had a capacity of 171 kv-a. at 2380 volts as determined from measurements. Based on the generating capacity of 625 kv-a. the following range of line constants was available in each transmission line:

Resistance 0 per cent to 72 per cent.
Reactance 0 per cent to 134 per cent.

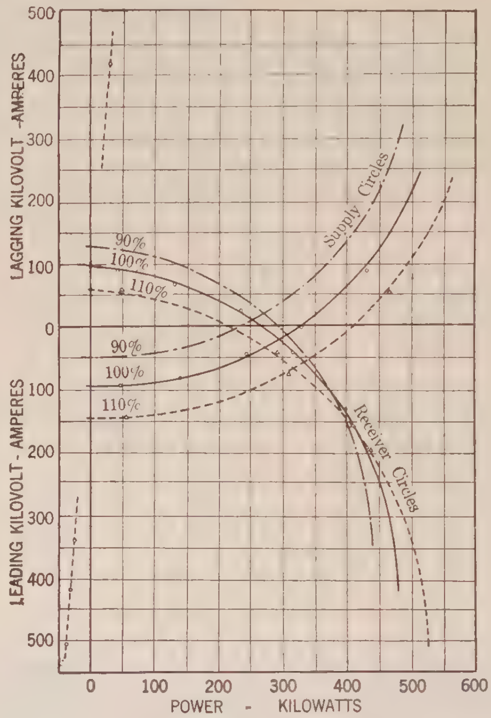


Fig. 16—Test Line Similar to an Actual 250-Mile Line

Refer to Fig. 13 for connections.
$Z = 0.80 + j\,12.12$ ohms.
$Y = + j\,0.032$ mhos.
Supply voltage maintained constant at 2380 volts = 100 per cent.
Circles show relation between power and reactive kv-a. for 90 per cent, 100 per cent, 110 per cent receiver voltages.

Measurements of the power and reactive kv-a. being transmitted over the line were made at $a$ and $b$ in Fig. 13. The losses in the synchronous condenser are therefore included with the kilowatts transmitted and the reactive kv-a. measurements include that supplied by the synchronous motors as well as the synchronous condenser.

*Test No. A-1:*

In this test the power limit was determined for a transmission system having line characteristics as determined from the circle diagrams similar to those of an actual 250-mile transmission line. The schematic diagram of the connections used in the test is shown by Fig. 13. Power was obtained from the 625-kv-a. generator and its voltage regulator was set to maintain 2380 volts at $a$, the supply end of the line. To simulate a high-voltage transmission line the resistance

was made small compared with the reactance. Referring to Fig. 13 the impedance and admittance of the line to neutral were as follows:

$$Z = 0.80 + j\,12.12 \text{ ohms.}$$
$$Y = +j\,0.0302 \text{ mhos.}$$

The receiver and supply circle diagrams of the line calculated from these constants are shown by Fig. 16. On Fig. 17 the curves drawn in full show the reactive kv-a. which must be drawn over the line to maintain various receiver voltages at a number of kilowatt loads transmitted over the line. These curves were derived from Fig. 16. Superposed on these curves are the chain dotted curves which show the relation between voltage and reactive kv-a. delivered by the *load and synchronous condenser* at a number of constant field currents. These curves were obtained by adding to the condenser characteristic curves the reactive kv-a. taken by the motor generator sets at different voltages for the condition with the synchronous motors taking a constant load of 450 kw. at the field excitation used during the test.

Actual test points are shown on the 100 per cent and

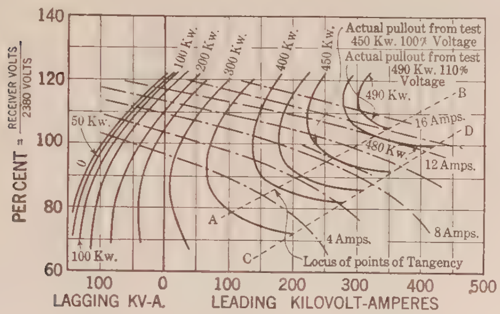


Fig. 17

—— Curves show relation between receiver volts and reactive kv-a. for different loads. These curves obtained from receiver circles on Fig. 16.

-·-·- Curves show relation between load voltages and reactive kv-a. delivered by *load and synchronous condenser* for different condenser field currents. Reactive kv-a. supplied by M. G. sets based on field excitation used in test and a constant load of 450 kw. with variable voltage.

110 per cent receiver and supply circles in Fig. 16. Referring to Fig. 17 pull-out occurred suddenly at 450 kw. at 100 per cent receiver voltage when the load was gradually increased. These pull-out points are quite close to "*A-B*" the calculated limit of stable operation. Up to 432 kw. at 100 per cent voltage all conditions were very stable. Above this load as 450 kw. was approached the kilowatts and voltage were very stable but the reactive kv-a. fluctuated considerably as would be expected because the curves in Fig. 17 are approaching tangency.

The oscillogram shown by Fig. 18 was taken at the pull-out point. The load was brought as near as possible to the pull-out point, and the oscillograph started. The load was then suddenly increased to slightly more than 450 kw. causing pull-out to occur.

During the test the dash pot on the voltage regulator was loosened so that the regulator was not "dead beat" and the resulting voltage fluctuations caused hunting to take place. The synchronous motor load takes a constant kilowatt load at all voltages, therefore, as the voltage changes the power component of current also changes. The power component of current drawn through the reactance of the line produces a shift in phase between the supply and receiver voltages. The synchronous motors hunt in attempting to follow the continual shift in phase of the receiver voltage. With

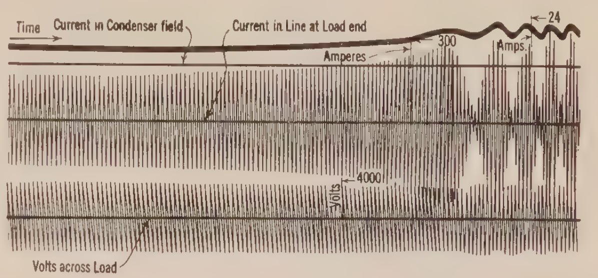


Fig. 18—Pull-Out at Power Limit

proper damping of the voltage regulator there was no difficulty from hunting.

*Test No. A-2:*

This test was made on a transmission system having line characteristics similar to those of an actual 500-mile line.

The test line was built up by connecting in series two sections, each identical with the transmission line used in Test *A*-1. The connection was identical with

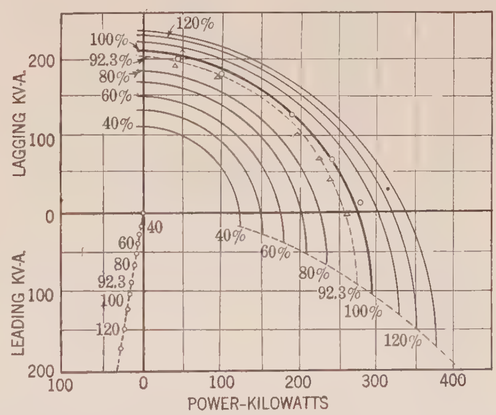


Fig. 19—Receiver Circle Diagram of Test Line Similar to an Actual 500-Mile Line

Two lines same as the one covered by the circle diagram on Fig. 16 connected in series. Connections identical with Fig. 22, except synchronous condenser No. 1 was disconnected.

$Z = Z = 0.80 + j\,12.12$ ohms. $Y_1 = Y_2 = j\,0.0302$ mhos.

See Fig. 20 for supply circles.

Supply voltage kept constant at 2380 volts equals 100 per cent. Circles show relation between power and reactive kv-a. at receiver for various receiver voltages.

Fig. 22 except that synchronous condenser No. 1 at the mid-point was disconnected.

Referring to Fig. 22:

$$Z_1 = Z_2 = 0.80 + j\,12.12 \text{ ohms.}$$
$$Y_1 = Y_2 = +j\,0.0302 \text{ mhos.}$$

The receiver cable diagrams calculated with these constants are shown by Fig. 19 and the supply circle diagrams by Fig. 20. The curves drawn in full on Fig. 21 show the relation between voltage and reactive kv-a. at the receiver end of the line for a number of different kilowatt loads transmitted. These curves were derived from the receiver circles on Fig. 19. It should be noted that with the power transmitted remaining constant an *increase* in lagging kv-a. drawn over the line will

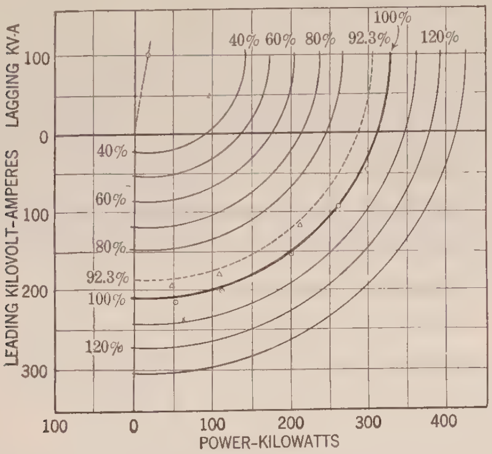


Fig. 20—Supply Circle Diagram of Test Line Similar to an Actual 500-Mile Line

For line constants, see the receiver circle diagram on Fig. 19. The supply voltage is constant at 2380 volts = 100 per cent. The circles show relation between power and reactive kv-a. at the supply end for various receiver voltages.

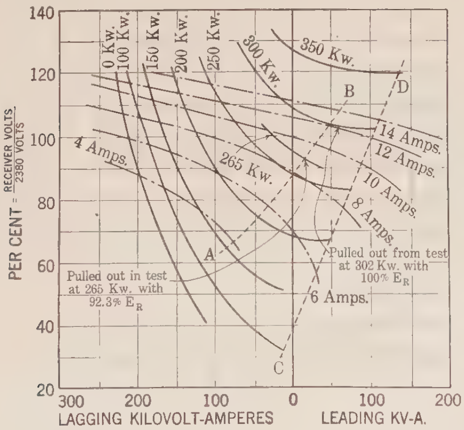


Fig. 21—Test Line Similar to an Actual 500-Mile Line

Connections same as Fig. 22, except synchronous condenser No. 1 disconnected; circle diagram and constants of the line shown on Fig. 19. ———— Curves show relation between receiver volts and reactive kv-a. for different loads. These curves obtained from receiver circles on Fig. 19. - — - — Curves show relation between load voltage and reactive kv-a. delivered by *load and synchronous condenser* for different condenser field currents. Reactive kv-a. supplied by *M. G.* sets based on field excitation used in test and a constant load of 300 kw. with variable voltage.

*increase* the receiver voltage. This relation, which exists on a 500-mile transmission line as pointed out previously, is different from ordinary operating conditions.

Actual test points at 92.3 per cent, 100 per cent and 110 per cent voltage are shown on Fig. 19 and 20. Referring to Fig. 21 it may be seen that pull-out occurred at 302 kw. at 100 per cent voltage and 265 kw. at 92.3 per cent receiver voltage, which points are very close to the calculated instability line "$A - B$." It happens that the characteristic curves of the line

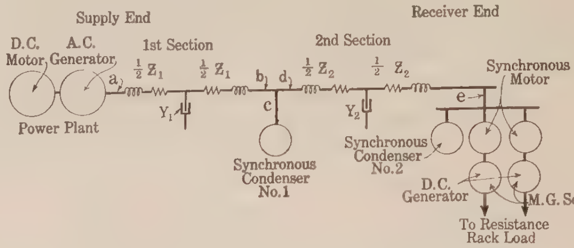


Fig. 22—Transmission Line with Synchronous Condenser at Mid-Point

Line is three-phase.
$Z_1$ = Impedance to neutral of 1st section.
$Z_2$ = Impedance to neutral of 2nd section.
$Y_1$ = Admittance to neutral of static condenser on 1st section.
$Y_2$ = Admittance to neutral of static condenser on 2nd section.
Measurements made at *a-b-c-d-e*.

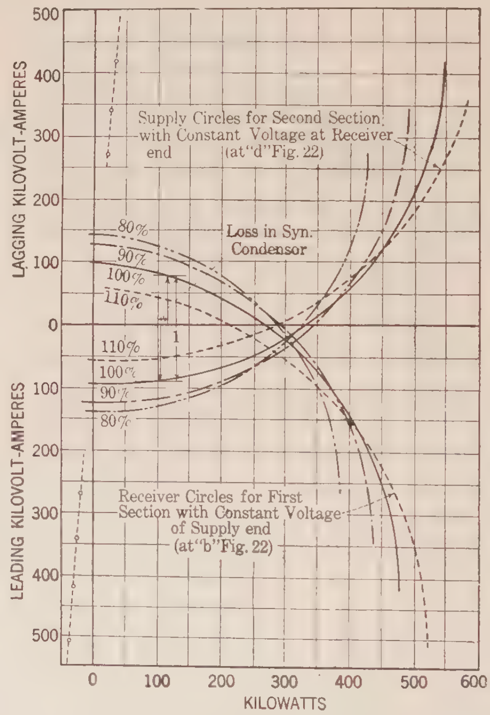


Fig. 23—Mid-Point of Test Line Which is Similar to an Actual 500-Mile Line

2380 volts = 100 per cent maintained at supply end of first section and receiver end of second section. Each section identical with Fig. 16. Referring to Fig. 22 the line constants to neutral are: $Z_1 = Z_2 = 0.80 + j\,12.12$ ohms.

$Y_1 + Y_2 = j\,0.0302$ mhos.

1 = lagging kv-a. which must be supplied at mid-point to maintain 100 per cent voltage when the load at the receiver end of first section is 117 kw. To obtain the lead at the end of the line subtract losses in synchronous condenser and the second section. By continuing this process curves showing relations between volts and reactive kv-a. at different loads as in Fig. 24 were obtained.

and synchronous apparatus become tangent very close to the power limit of the line alone. Within the above range of load the voltage regulator functioned perfectly even though an increase in receiver voltage

required an increase in the lagging kv-a. drawn over the line, because an increase in condenser excitation always produced a rise in receiver voltage as long as operation was above "*A—B*" in Fig. 21.

*Test No. A-3:*

This test was made to check the operation of a loaded transmission line. Conditions were identical with those in Test *A*-2 except that synchronous condenser No. 1 was connected at the mid-point of the line as is shown by Fig. 22. The voltage regulators were set to maintain 100 per cent voltage (2380 volts) at the mid-point of the line as well as at the supply and receiver ends.

Fig. 24 shows the line and synchronous condenser characteristics at the middle of the line. These curves were obtained in the same manner as previously described for Fig. 8.

The load was gradually increased and the following readings taken:

SUPPLY END OF 1ST SECTION (AT *a* FIG. 22)

| Reading No. | Volts | Line Amps. | Kw. | Reactive Kv-a. |
|---|---|---|---|---|
| 1 | 2380 (100%) | 26.5 | 64 | − 90 |
| 2 | " (100%) | 35 | 120 | − 83 |
| 3 | " (100%) | 50 | 196 | − 62 |
| 4 | " (100%) | 61 | 248 | − 38 |
| 5 | " (100%) | 77.5 | 320 | ... |
| 6 | " (100%) | .. | 430 | Pulled out |

did not actually occur until the load was increased to 384 kw. This point was checked by several trials.

The addition of the synchronous condenser at the

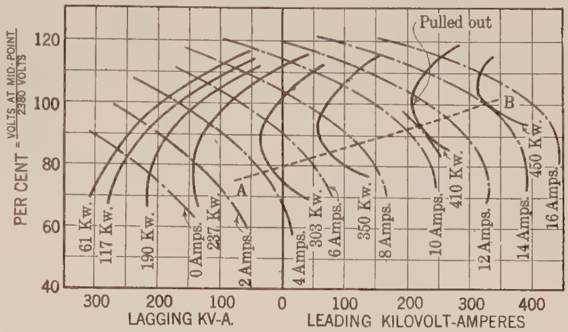


FIG. 24—MID-POINT OF TEST LINE SIMILAR TO AN ACTUAL 500-MILE LINE

Constant voltage = 2380 volts = 100 per cent *E* maintained at receiver and supply ends of the line.

———Curves show relation between volts at mid-point and reactive kv-a. which must be supplied by the synchronous condenser for kw. measured at "*B*" on Fig. 22. The load actually delivered at receiver end of the line can be obtained by substracting the losses in the synchronous condenser and 2nd section.

- — - —Curves show relation between synchronous condenser voltage and reactive kv-a. delivered for particular values of field current. Data for curves giving relation between volts and reactive kv-a. at mid-point obtained from Fig. 23.

mid-point of the line used in Test *A*-2 increased the load that could be delivered over the line from 302 kw. to 384 kw., an increase of 26 per cent.

MID-POINT OF LINE. (See Fig. 22)

| | End 1st Sect. (at *b*). | | | Syn. Cond. No. 1 (at *c*). | | | Begin 2nd Sect. (at d). | |
|---|---|---|---|---|---|---|---|---|
| Reading No. | Volts | *K. W. | Reactive Kv-a. | *Field Amps. | K. W. | *React. Kv-a. | K. W. | React. Kv-a. |
| 1 | 2380 (100%) | 62 | + 87 | 3.9 | 16 | + 175 | 45 | − 90 |
| 2 | " (100%) | 117 | + 75 | 4.4 | 15 | + 158 | 102 | − 85 |
| 3 | " (100%) | 190 | + 47 | 5.1 | 15 | + 116 | 171 | − 70 |
| 4 | " (100%) | 237 | + 23 | 5.8 | 15 | + 75 | 224 | − 52 |
| 5 | " (100%) | 303 | − 21 | 7.3 | 15 | 0 | 286 | − 23 |
| 6 | " (100%) | 410 | Pulled Out | | | | | |

*May be used to check calculated curves in Fig. 24.

RECEIVER END OF 2ND SECTION (At *a* Fig. 22)

| Reading No. | Volts | Line Amps. | Kw. | Reactive Kv-a. |
|---|---|---|---|---|
| 1 | 2380 (100%) | 22 | 45 | + 82 |
| 2 | " (100%) | 30.5 | 99 | + 72 |
| 3 | " (100%) | 41.6 | 170 | + 47 |
| 4 | " (100%) | 52.5 | 219 | + 25 |
| 5 | " (100%) | 67.5 | 278 | − 11 |
| (Extra) | " (100%) | .. | 302 | − 55 Meters all were steady |
| 6 | " (100%) | | 384 | Pulled out |

Considering the two sections independently the kilowatts and reactive kv-a. at their supply and receiver ends may be checked against the 100 per cent circles shown on Fig. 16.

For loads above 330 kw. at *e* (Fig. 22), the receiver end of the line, which corresponds to 370 kw. at *b*, the reactive kv-a. fluctuated to a limited extent although the voltage and power remained steady. At a load of 340 kw. at *e*, (380 kw. at *b*) the system showed signs of becoming unstable although pull-out

An investigation at a number of different loads was made of the effect of suddenly throwing on about 25 per cent additional load. About 25 per cent of the load measured at *e* (Fig. 22) was taken off and then suddenly applied again by manipulating the switches on the resistance rack used as load for the motor generator sets. The amount of load thrown on and off is the difference between "on" and "off" in the tabulation below.

| Trial No. | Kw. at *e* On | Off | On | Remarks |
|---|---|---|---|---|
| 1 | 293 (321) | 243 (263) | 293 (321) | Stabilized rapidly. |
| 2 | 320 (360) | 283 (308) | 320 (360) | Voltage oscillated ± 10 per cent at first but settled down after a few oscillations. |
| 3 | 344 (384) | 300 (330) | | Pulled out when load was thrown back. |

The figures given refer to kw. at the receiver end of

the line and for convenience in referring to Fig. 24, the corresponding kw. at $b$ are given in brackets.

*Test No. A-4:*

This test is identical with Test $A$-3, except that one motor generator set was moved from the receiver end of the line to the mid-point of the line and operated in parallel with synchronous condenser No. 1. The loads were adjusted so that about one-half of the load was delivered at the mid-point, and the other half transmitted to the end of the line. The loads were gradually increased until pull-out took place.

When pull-out occurred 440 kw. (measured at $b$) were being transmitted over the first section. This is very close to the pull-out point of the first section when tested alone, which was 450 kw. in Test $A$-1. Up to 400 kw. (at $b$) the system would stabilize quickly after a sudden change in load.

In test $A$-3 with the synchronous condenser No. 1 alone at the mid-point pull-out occurred at 410 kw. at $b$, while in this test with the motor generator set operating in parallel with the condenser pull-out occurred at 440 kw. This is to be expected because the additional synchronous capacity at the mid-point

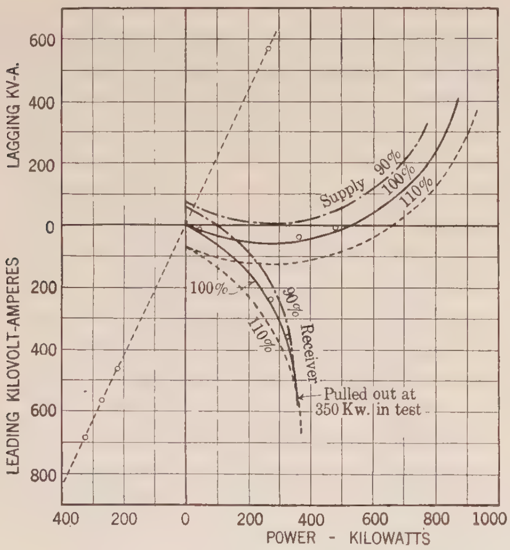


Fig. 25—Test Line Receiver and Supply Circles

Refer to Fig. 13 for connections.
$Z = 3.84 + j\,8.08.$
$Y = 0$
Supply voltage maintained constant at 2380 volts = 100 per cent.
Circles show relation between power and reactive kv-a. for 90 per cent, 100 per cent, 110 per cent receiver voltages .

changes the slope of the chain dotted curves in Fig. 24 in such a manner as to increase the power limit, in other words it gives the effect of a larger synchronous condenser at the mid-point.

*Test No. B-1:*

This test was made on a transmission line having an impedance to neutral of:

$$Z = 3.84 + j\,8.08$$
$$Y = 0$$

This relation between resistance and reactance is typical of a lower voltage transmission line. The connections and apparatus employed are shown by Fig. 13. The circle diagrams calculated from the above constants are shown by Fig. 25. Fig. 26 shows the characteristic curves of the line and synchronous load superposed upon each other.

The test results have been plotted on Fig. 25. The points checked the calculated circle diagrams very closely, particularly the higher readings because the circle diagrams were based on resistance of the grids

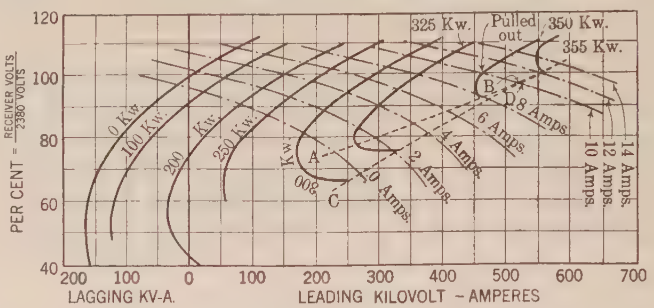


Fig. 26—Receiver End of Line in Test B-1

2380 volts = 100 per cent voltages.
———Curves show relation between receiver volts and reactive kv-a. at different loads. These curves obtained from receiver circles on Fig. 25. The supply voltage was constant at 2380 volts = 100 percent.
- — - —Curves show relation between load voltages and reactive kv-a. delivered by *load and synchronous condenser* for different condenser field currents. Reactive kv-a. supplied by *M. G.* sets based on field excitations used in test and a constant load of 350 kw. with variable voltage.

at the higher loads. Pull-out occurred very sharply at 350 kw. without much sign of instability below this load, as would be expected by referring to Fig. 26 since the two families of curves approach tangency abruptly very close to the maximum power point of the line.

*Test No. B-3:*

Two transmission lines each identical with the line used in Test $B$-1, were connected in series as shown on Fig. 22, except that synchronous condenser No. 1 was disconnected. The line constants then were:

$$Z_1 = Z_2 = 3.84 + j\,8.08 \text{ ohms}$$
$$Y_1 = Y_2 = 0$$

Pull-out took place at 190 kw. which corresponded closely to the pull-out point of the line alone as determined from the calculated circle diagram. The characteristic curves of the line and synchronous apparatus become tangent to each other practically at the pull-out point of the line. The circle diagram of the line and characteristic curves of the line and synchronous apparatus are not shown.

*Test No. B-4:*

To determine power limit of a "loaded" transmission line synchronous condenser No. 1 was connected at the middle of the line used in Test $B$-3. The connections were then exactly in accordance with Fig. 22.

The load was gradually increased with the voltage regulators set to maintain constant voltage at $a$-$b$-$e$ and the following readings taken:

(SUPPLY END OF 1ST SECTION At *a* Fig. 22)

| Reading No. | Volts | Line Amps. | Kw. | Reactive Kv-a. |
|---|---|---|---|---|
| 1 | 2380 (100%) | 14 | 61 | − 10 |
| 2 | " (100%) | 50 | 208 | − 31 |
| 3 | " (100%) | 82 | 345 | − 32 |
| 4 | " (100%) | 134 | 550 | ... |

voltage regulator would operate satisfactorily almost up to the point where pull-out occurred.

Each of the two transmission line sections may be considered individually and the receiver and supply test points checked against the circle diagrams for the single section used in Test *B*-1 which are shown by Fig. 25.

MID-POINT OF LINE. (See Fig. 22).

| Reading No. | Volts | End of 1st Sect. (at *b*). Kw. | React. Kv-a. | Syn. Cond. No. 1 (at *C*). Field Amps. | Kw. | React. Kv-a. | Begin 2d Sect. (at *d*). Kw. | React. Kv-a. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2380 (100%) | 61 | − 17 | 7.0 | 14 | + 8 | 47 | − 25 |
| 2 | " (100%) | 174 | − 94 | 7.9 | 15 | − 45 | 158 | − 49 |
| 3 | " (100%) | 264 | − 200 | 10.0 | 17 | − 144 | 250 | − 53 |
| 4 | " (100%) | 350 | − 427 | 15.5 | 20 | − 380 | 330 | − 47 |

RECEIVER END OF 2ND SECTION (At *e* Fig. 22)

| Reading No. | Volts | Line Amps. | Kw. | Reactive Kv-a. |
|---|---|---|---|---|
| 1 | 2380 (100%) | 14 | 48 | − 34 |
| 2 | " (100%) | 41 | 148 | − 92 |
| 3 | " (100%) | 62 | 208 | −156 |
| 4 | " (100%) | 84 | 268 | −229 |

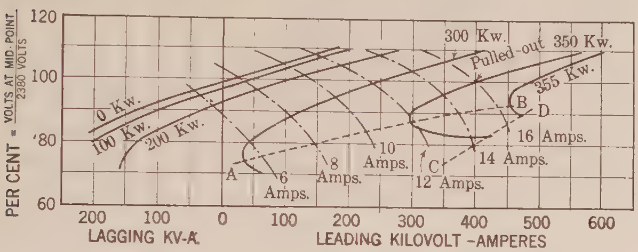


FIG. 27—MID-POINT OF TEST LINE USED IN TEST B-4

Refer to Fig. 22 for connections. $Z_1 = Z_2 = 3.84 + j\,8.08$ ohms. $Y_1 = Y_2 = 0$.

Constant voltage = 2380 volts = 100 per cent maintained at receiver and supply ends of the line (*i. e.* at "*A*" Fig. 22).

————Curves show reactive kv-a. which the synchronous condenser at the mid-point must supply, to maintain various voltages at a number of different loads in kw. measured at receiver end of 1st section (at "B" on Fig. 22). The load actually delivered at the receiver end of the line (at "*E*" Fig. 22) can be obtained by subtracting the losses in the synchronous condenser and second section.

- — - —Curves show relation between synchronous condenser voltage and reactive kv-a. delivered for particular values of field currents (from Fig. 15). Note the large increase in reactive kv-a. between 350 and 355 kw.

Immediately after reading No. 4 was taken the system pulled out of step without any further increase in power having been made. This indicated that reading No. 4 was very close to the pull-out point. The system was very stable when this reading was taken so that all the meters could be read accurately.

The conditions at the middle of the line were as shown on Fig. 27. The curves were derived in the same manner as the corresponding curves used with Test *A*-3. The family of receiver and supply circles from which these curves were derived are not shown. From Fig. 27 it can be seen that the transmission line and the condenser characteristic curves become tangent to each other practically at the pull-out point for the first section, that is, slightly above 350 kw. as measured at point *b* (Fig. 22). Since the curves became tangent very suddenly it was to be expected that the

At reading No. 4 with 134 amperes in the first section and 84 amperes in the second section the per cent resistance and reactance voltages in each section are as follows:

1st Section $I\,R \div j\,I\,X$ = 37 per cent + $j$ 79 per cent

2nd Section $I\,R \div j\,I\,X$ = 22 per cent + $j$ 49 per cent

There was no tendency toward hunting even with such high percentage resistance and reactance drops. The system stabilized after a few oscillations following a sudden change in load, provided the maximum swing did not exceed the pull-out point of the system.

As determined from Test *B*-1 350 kw. was the maximum power which could be transmitted the first section. In Test *B*-3 two such lines were connected in series without a synchronous condenser at the mid-point and pull out occurred at 190 kw. With the circuits arranged as in Test *B*-3, but with a synchronous condenser at the mid-point, 268 kw. could be transmitted. The addition of the synchronous condenser at the mid-point raised the power limit 40 per cent.

*Other Tests:*

A large number of other tests were made on hunting and the effect of short circuits in causing pull-out to occur. The results are given in the summary.

SUMMARY

1. A method of determining the power and voltage stability limit of a transmission system taking into account the characteristics of the synchronous condensers and load in conjunction with the characteristics of the line is described.

2. The power limit of a straight 500-mile transmission line is calculated by this method. The power limit is also calculated for the same line with a synchronous condenser at the mid-point which divides the line into two sections. The addition of the synchronous condenser at the mid-point increased the power limit 42 per cent.

3. Tests were made on a 625-kv-a. transmission system operated at 2300 volts to determine experimentally the power and voltage stability limit of a transmission line with a synchronous condenser at the mid-point. The tests check closely with the calculated values.

4. Tests on hunting caused by prime mover pulsations, line characteristics, and voltage regulator adjustment were made.

5. It was found that the damper windings on synchronous condensers do not have much effect in reducing hunting, particularly at resonant points. There was practically no difference between the standard high-resistance windings used for starting purposes and low-resistance copper damper windings.

6. On a high-resistance and low-reactance transmission line hunting was found to occur at high condenser field excitations. The addition of reactance stabilized the system. On high-voltage transmission lines the reactance is high as compared to resistance and no difficulty from hunting due to line characteristics is to be expected.

7. A loose adjustment of the voltage regulator dash pot was found to set up hunting.

8. Short circuits were applied through reactance to a system carrying load to determine the severity and duration of a short circuit required to cause the system to pull out of synchronism. The time element between the application of the short circuit and pull-out was found to be due to the time required to reduce the voltage to a point where the power limit of the system was exceeded at the reduced voltage as can be seen from Fig. 30. The pull-out point which is not shown on the oscillogram occurred 1½ seconds after the application of the short circuit.

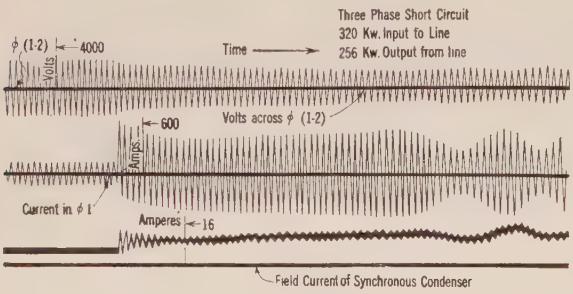


Fig. 30

9. At a distributing center for power supplied from a high-voltage transmission line it is extremely undesirable for a short circuit on one of the lower voltage lines to be able to cause the entire system to pull out of step. On a loaded line where power is distributed from loading points there should be sufficient reactance between the transmission and distribution lines to prevent a short circuit on the distribution system from causing the entire transmission system to pull out of step.

## OVER-WATER TRANSMISSION LINE

Japan will soon have the longest over-water electric transmission line in the world—a 100,000-volt line between the island of Shikoku and the mainland, twenty-three miles away. Intervening islands will carry the towers.

## SAFEGUARDING IDLE GENERATORS

BY G. MONSON

From past experience, in connection with generator winding breakdowns, we have come to the conclusion that many of these breakdowns have been due to moisture, or water getting into the machines, causing concentration of corona on the winding where the drops of water were located.

Generators may be shut down frequently, from one cause or another, such as lack of load, repairs, cleaning, etc. If the generator when standing still is allowed to cool off below the room or ingoing temperature—say at night; or from doors or windows being left open during cool weather; or if the generator is of the enclosed type, taking air from outside the building, or from the basement, and discharging it to the outside, having a chimney draft effect through the generator chilling the same—then if the generator is heated up by a quick change in temperature, either when standing still, or when started up with load, condensation will occur both in the stator and the rotor, the water dripping all over the windings.

This water is the cause of considerable trouble from corona after the generator is started and running with full potential. From tests made we have found that these drops of water will show fire with relatively low voltage applied on the coils, and that the fire increases in density with increased voltage, and it is only a matter of time before the winding is injured sufficiently to break down at its weakest point.

To safeguard against this enemy of the generator when idle, it is suggested that the machine be kept moderately warm at all times (slightly above room or ingoing air) which can be accomplished in several ways—by installing steam pipes in the air entrance or in the shields; by the use of electric heaters; or by supplying current to the windings.

It is important that the managers of all power stations should be informed of this lurking danger to their generators, and to be prevailed upon to better safeguard their machines, which also means prolonged life for the generators.

## EFFECT OF VULCANIZATION ON CABLE INSULATION

During January the Rubber Section of the Bureau of Standards carried out some work on the effect of variations in vulcanization on the electrical properties of rubber insulating materials for cables. A number specimens of the compound, smoked sheets, 92 per cent and sulphur 8 per cent, were prepared for the purpose of determining the effect on the electrical properties of conducting vulcanizing at different temperatures and for different lengths of time. The results indicate that for a given state of cure the electrical properties are practically independent of the means by which that cure was effected, whether by vulcanizing for a long time at a low temperature or a shorter time at a high temperature.

# The Present Trend of Electrical Safety in Coal Mines

BY L. C. ILSLEY
Member, A. I. E. E.
Electrical Engineer, U. S. Bureau of Mines

BACK of every safety program there stands the industry itself with its precedents, prejudices and traditions. Coal mining, being an old established industry, naturally had many fixed traditions long before electricity and electrical equipment, comparatively new forces, made their appearance.

The electrical engineer, in spite of these traditions, thrust himself and his equipment into this field and insisted, often without invitation, upon taking a prominent part in the future development of coal mines. Therefore, it naturally follows that certain readjustments must be made from time to time to take care of the new problems introduced by electricity. Further, these adjustments will never be permanently or satisfactorily made until the electrical engineer, the mining engineer and the safety engineer thoroughly understand each other's problems and jointly work out a practical solution based upon the needs of industry and the limitations of electrical design.

The safety movement in coal mining had made considerable advance before the advent of electricity. As early as 1869 we find a safety code, covering one county in the anthracite field of Pennsylvania, and by 1888 there were at least 12 states having safety regulations for bituminous coal mines. These early safety codes, coming in previous to the introduction of electricity, naturally had no reference to it or to the installation and operation of electrical apparatus, and in some states, after successive revisions of the safety code, there are still found no adequate rules covering electrical equipment. For instance, a chief mine inspector or his deputy, is not, as a rule, legally required to have a knowledge of electricity or an understanding of safety measures concerning the installation of electrical equipment.

The growth of the coal industry in the United States has been remarkable. Yearly tonnage statistics, published by the Geological Survey for both anthracite and bituminous mines since 1822, not only show the rapid growth of this industry, but also indicate the part which electricity has played in bringing the total output of coal to the present figures.

Beginning with 58,583 tons in 1822, there is almost an unbroken yearly increase until we reach the maximum of 678,211,904 tons in 1918. An increase of 10,000 per cent in a little less than 100 years.

The increase in bituminous production during each decade for the last 50 years is shown in Table I.

*To be presented at the Spring Convention of the A. I. E. E., Birmingham, Ala., April 7-10, 1924.*

TABLE I.
Showing the increase in bituminous coal production in the United States.*

| Decades | Average yearly production—tons |
|---|---|
| 1871 to 1881 | 32,600,000 |
| 1881 to 1891 | 82,800,000 |
| 1891 to 1901 | 148,500,000 |
| 1901 to 1911 | 323,000,000 |
| 1911 to 1921 | 486,800,000 |

*Compiled from data given in Geological Survey Technical Paper 11:34, 1923.

The increase in coal output during the last 25 years has been augmented by the introduction of electrical equipment which, owing to both economy of operation and flexibility, has found a real place in the industry. It was impossible to find suitable statistics showing the growth in the use of electrical equipment in coal mines. However, Table II has been compiled from such data as could be found. This table gives an indication of increases during the last two decades.

TABLE II.
Showing increase in the use of electrical equipment in bituminous mines from 1901 to 1919*

| Year | No. of motors | Total h. p. of motors |
|---|---|---|
| 1902 | 1,322 | 65,927 |
| 1909 | 10,557 | 402,090 |
| 1919 | 42,230 | 1,578,474 |

*Compiled from the Thirteenth and Fourteenth U. S. Census Reports covering mines and quarries.

Electrical equipment, owing to its flexibility, has become an essential part of the modern coal mines. In the old days there were hazards from open lights, from smoking, and from explosives. When you bring electrical equipment into the mine you add several new hazards. These hazards are real and should be given the same consideration that was given to the old type of hazard.

The first hazard is that of electrical shock. No person can be sure that he will not be killed, even from a 110-volt circuit, if his body makes proper contact with the circuit, so as to cause the maximum current to pass through his body. As the voltage is increased to 250 volts, 500 volts, or 2300 volts, the danger from contact with the electric circuit is increased. Alternating current of the same nominal voltage is possibly more dangerous than direct current. Experience has taught us that both will cause death, and if the fatalities from this source are to be kept low, certain precautions in the guarding of circuits must be observed.

A second hazard is in the use of explosives in conjunction with electric current. It seems unnecessary to advise against the placing of any electric wiring in a powder magazine. If a flash or arc from an electric circuit comes in contact with black powder, an explosion results. Therefore, all boxes and care should be so constructed that current from the trolley or from the rail cannot possibly pass through the sides of boxes, and so that is impossible for the metal powder cans to form a path for the electric current. The electric current is very useful for electric shot-firing, and undoubtedly safer than fuse and squib firing, but great care must be taken against premature firing, due to an accidental current passing through the electric detonator. Detonators and explosives should always be kept separate until used, also great care should be used in keeping shot-firing wires from other electric wires, and finally, detonator leads should be prevented from contact with electrical circuits or apparatus, since less than 1 ampere of electric current will fire an electric detonator.

A third source of danger is the ignition of gas from electric flashes or heated wires. It takes but a tiny current at 250 volts to ignite gas. It has been found that the current required to operate an electric drill motor under no load is ample to cause an ignition. Again, the incandescent filament of a 2-volt, 1-ampere, bulb will ignite gas very readily.

A fourth hazard is the ignition of coal dust by electric arcs or flashes. Some very bad coal mine disasters have undoubtedly been caused in this way. Tests made by Wm. Thornton in England and by H. H. Clark of the U. S. Bureau of Mines proved that ignition of clouds of coal dust by electric flashes could readily take place. The greatest danger occurs, in case of a wreck of a trip of cars, which wreck may tear down or damage an electric circuit and at the same time stir up a heavy dust cloud.

A fifth danger is from fires of electric origin. These may be caused by short-circuited cables, by grounded feeder or trolley circuits, by grounded lighting circuits, by overheated motors or starting devices, by heating from incandescent lamps improperly placed with reference to flammable material, or by short-circuited transformers or defective switches.

The foregoing hazards, which have been added as a result of bringing electricity into coal mines, concern various groups of men and organizations connected with the industry. They effect the economical welfare of the operator, and the personal safety of the miner. They are intimately associated with the legal and moral obligations of state inspection departments and have a financial interest to underwriters of compensation insurance. They affect, in a competitive way, the policies of the manufacturer of electrical apparatus and machinery, and they interest, from a humane standpoint, the U. S. Bureau of Mines.

### The Coal Mine Operator

From a humanitarian standpoint, the operator should be concerned with the safety of his employees. The woe caused by one bad disaster is so great as to make the most hardened wish to escape any direct responsibility for its cause. The operator has an economic interest in this question. He cannot afford to have his mine wrecked by explosion or destroyed by fire, neither can he afford to pay excessive insurance rates or heavy death benefits.

The operator of the present in various ways is trying to help the situation. He attends and takes part in local and national organizations where questions relating to the safety of coal mining are discussed. He organizes safety committees among his employees, and sends them to compete in state and national first aid and safety contests. He employs safety inspectors who spend their entire time looking into the safety of mines. He makes use of government bulletins and of the advice of government experts when safety questions arise. He assists in preparing adequate safety codes for the protection of his mine.

The operator should also be given credit for what is perhaps the most forward step in regard to electrical safety in coal mines, namely, the introduction of the "wireless mine." The possible hazards of extensive electric wiring in gaseous and dusty coal mines are so great that at least two large coal mine operators, one in West Virginia and one in New Mexico, are laying their plans for an electrically operated mine without permanent electric wiring. Why does one install wires? The answer is, for transmitting energy from the power plant to the place where energy is used. If the power plant could be located at the coal face, no permanent wires would be needed. Then, if wires are potential danger, let us do away with them and place the power plant on wheels, taking it to the point where energy is needed. Any piece of work can be done better by energy obtained from a constant source of potential, such as would be delivered by a storage battery, provided the battery is large enough for the job. Having no wires to install, no tracks to bond, no voltage drop-over long-feed lines to consider, one can afford to invest heavily in a portable power plant. When the advantages from a safety standpoint are considered, the venture is certainly worth a thorough tryout.

Imagine the security the operator of a "firey" mine could feel at the end of the shift, knowing that there are no feeder or trolley circuits to become grounded over night, no switches to be left closed when they should have been left open, that when the mine stopped its work all its electrical equipment came out of the mine or at least was brought to a fresh air base to remain there until the next day's work begins.

The wireless mine has the advantage of having the equipment that carries the live electric current always

under close supervision and also in that such equipment will only be in the gaseous portion of the mine during the working shift, whereas, under the system of wired mines, the wires are there all the time, a large portion of which time they may be without close supervision.

The operator is demanding safe electrical equipment. One manufacturer of approved equipment reports 300 per cent increase in sales during 1923 as compared with the sales of any previous year. The operator is not only demanding more approved equipment, but is asking for new lines of approved equipment such as hoists, air compressors, pumps, and loading machines.

### The Miner

The miner should be the most interested of all in electrical safety, since it is his life that is at stake. Even if he escapes with his life, the destruction of the mine property may result in a long period of idleness with consequent financial embarrassment.

The miner in times past has seemed to stand in the way of improvements that would benefit him most of all. In some sections, even today, he is against any innovation, apparently believing that any change, especially if proposed by the operator, must necessarily be detrimental to his interests.

Gradually, however, it is believed that the miner is having more faith and taking more interest in safety measures as illustrated by the following: Already there are over 80 Joseph A. Holmes Safety Chapters, chiefly organized from the coal mines. Safety articles issued by the Bureau of Mines are being reprinted in his journal. The mining member of the Commission, appointed to revise the Safety code for Maryland, called in the Bureau of Mines to assist in bringing about a practical and efficient safety code. The miners are using daily nearly 200,000 electrical lamps approved for safety and in many cases they would refuse to work if they could not have them. In a great many instances they are paying for the maintenance of these lamps.

The safety engineer should make it a part of his duty to so instruct the miner in safety work that he will be the strongest advocate for bettering conditions.

### The State Inspector

The state and deputy inspectors are intimately connected with all branches of mine safety work. Many of them spend nearly all their time in inspection work underground. These questions relating to electrical safety are giving them lots of worry. In some instances they do not feel certain as to the safety of a given electrical device, which the operator or the manufacturer may claim to be amply safe, but concerning which the inspector cannot obtain a guarantee as to its safety and has no ready means for conducting safety tests of the equipment to satisfy his doubts. In other cases he is hampered in enforcing rules and regulations he believes ought to be observed, because the mine safety code has not specifically covered the point in question.

This being the prevailing condition in a number of states, state inspectors welcome the approval system of the Bureau of Mines, which gives them a guarantee that equipment has been subjected to certain tests, and shares with them the responsibility for its good behavior in case it is properly maintained. As more of the approved type of apparatus is used, and less of the untried so-called "flame-proof" apparatus that has never been properly inspected or tested is found in mines, the burden on the state inspector is lessened.

The chief inspectors of several of the coal mining states have advised the Bureau of Mines to the effect, that where safe electrical equipment is required, they will accept the bureau's approval plate as standard for their state.

Perhaps the most encouraging evidence of the interest in electrical safety by state inspection bureaus is the action taken at the last annual meeting of the Coal Mine Inspectors Institute of America held at Pittsburg, Kansas, when the following resolution was passed:

> "That every possible effort be made to safeguard the use of electricity in mine operations and to this end we would request the U. S. Bureau of Mines to make every possible effort to discover means whereby electrical equipment in mines will be made as safe as possible and that special attention be given to the proper installation and care of the electrical transmission lines in mines."

### The Underwriters of Compensation Insurance

The various mine insurance companies are having a very beneficial influence on electrical safety. Their field inspectors make very rigid inspection and the mine rate for a particular mine or set of mines is based upon the result of these inspections. Unsafe electrical practises and equipment mean increased insurance costs for every $100.00 of payroll. The guarding of wires, the use of electric lamps instead of open lights, the careful upkeep of equipment, the maintenance of proper discipline, the use of approved equipment, all tend to lower the insurance rate. Also, the experience of a mine, namely, whether that mine has few or many accidents, determines somewhat its future insurance rate. Hence it pays an operator in dollars and cents to install safe equipment and to maintain it in the best possible condition.

The insurance companies have kept in close touch with the Bureau of Mines in regard to safety work in mines, and it is prophesied that there will come a time when it will be difficult for a mine operator, who neglects to adopt safe electrical equipment, to obtain compensation insurance.

### The Manufacturer of Electrical Equipment

The manufacturer of electrical equipment began almost immediately to design apparatus for use in gaseous and dusty mines. In his early work, however, he depended too much on theoretical design and did not sufficiently try out his designs under rigid service conditions. Many of these early designs which would not

stand the rigid test requirements of today are still in use, and where such are in gaseous and dusty mines they offer a possible electrical hazard.

In order to place the Bureau's approval work on a higher plane, permitting better and more rapid work to be done, several manufacturers combined to donate a large testing gallery to the Bureau. This gallery which has been in service nearly ten years has proved a great help to the Bureau in its testing work, and permitted much more work to be done. By this act the manufacturers have done much to forward electrical safety in mines.

In the future, as far as is feasible, it is understood that manufacturers intend to carry only two lines of equipment, the open type for non-gaseous mines, and the permissible type approved by the U. S. Bureau of Mines for use in gaseous and dusty mines, thus eliminating the so-called "flame-proof" type, built along the same lines but not having the careful factory inspection or the additional inspection and test given by the Bureau to permissible equipment.

The manufacturer is going to provide the coal mine operator with a complete line of approved electrical equipment for use in mines where such equipment is necessary. This means a large program for the manufacturer and a still larger program for the electrical testing section of the Bureau of Mines. The manufacturer's applications for tests and approval are coming in at a rapidly increasing rate. Not only is the manufacturer making application, but he is arranging a definite program for the design and construction of this equipment.

### The U. S. Bureau of Mines

The U. S. Bureau of Mines is generally recognized as a disinterested party in the electrical safety field. The Bureau's electrical safety work is along these general lines: 1. Investigations for State Departments upon their request; 2. Investigation as to the cause of electrical accidents; and 3. Investigation of electrical apparatus to determine its safety for use in atmospheres which may inadvertantly contain explosive accumulations of coal dust or methane. The third line of investigative work is at present occupying most of the time of the electrical testing force of the Bureau. This testing force comprises a personnel of seven engineers. Such apparatus and equipment as pass the safety schedules, laid down by the Bureau for standardizing safety equipment, are labeled with an approval plate which is a sign to the industry that the Bureau judges them to be safe if properly maintained.

Reports are issued from time to time covering the investigations, together with a description of apparatus which has been approved. The Bureau also periodically publishes a list of equipment which has passed its official schedule requirements. Undoubtedly, if approved aparatus becomes generally adopted in mines where dangerous conditions may prevail, electrical safety will be effectively increased.

## ELECTRICAL AUXILIARIES—MOTORSHIP "SEEKONK"

The motorship *Seekonk* recently returned to New York, completing her maiden voyage through the Panama Canal to Seattle and return, has given further demonstration of the successful operation of electrical auxiliaries.

It is difficult to believe that in a short space of time of a few years marine engineers who were so skeptica of electric motors for driving auxiliaries are now very loud in their praises of this form of power.

This praise has not been earned without labor on the part of the shipbuilder to determine the exact power and adaptability of the particular motor to the service required and the electrical manufacturer to produce motors to suit the shipbuilder's requirements and at the same time employ the best design, materials and efficiencies from an electrical standpoint.

The log of the vessel shows no involuntary stops or delays and when it is considered that electric motors must run continuously for the fuel oil, lubricating oil, cooling water pumps, without which the main engine cannot run, this initial voyage is exceptional.

Electricity plays a very important part in the performance of this vessel. The most important and perhaps the simplest system is the interlocking alarm for the failure of fuel oil, lubricating oil and the cooling water systems. This system, as well as, automatic electric hot water system for sanitary purposes, being novel. There are 20-gallon automatic hot water heaters installed in various sections, thus reducing the piping and the cooling effect, the water being maintained at 130 deg.

The steering gear is of the hydroelectric type, driven by remote-control electric motors which performed perfectly throughout the voyage.

All auxiliaries are electrically driven; windlass, capstan, ice machine, winches and all engine room auxiliaries, and the galley is equipped with electric heating devices. All power, as well as lighting is operated on a common 220-volt d-c. system.

Perhaps the most efficient cargo handling gear ever installed in a vessel is on the *Seekonk*. The switchboard is provided with watthour meters to measure the total current consumption of deck winches, as well as for various other purposes and the cost of fuel for handling cargo for the round trip was 0.305 cents per ton of cargo handled. The system makes use of dynamic lowering to a marked degree, attaining the safe motor speeds for lowering with capacity loads. The winches are of a unique design, all gears being in oil and they operated without a single failure during the entire trip.

# Theory of Three-Circuit Transformers

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***Review of the Subject.***—*The characteristics of three-circuit transformers, the literature of which is very meager, is discussed here in considerable detail. The features of the scheme of treatment are as follows:*

*1. The scope and general aspects of the problems of three-circuit transformers are reviewed.*

*2. Some peculiar phenomena of considerable theoretical interest are cited.*

*3. An electrical network equivalent to the magnetically interlinked circuits of a three-circuit transformer is developed, useful in visualizing the problem and in predicting by inspection a number of its characteristics.*

*4. Two physical interpretations of the equivalent network are given to assist the understanding of its principle and its applications.*

*5. The case of auto transformers interconnecting three circuits is interpreted so that the formulas developed for three-circuit transformers become universally applicable regardless of the presence or absence of metallic interconnection among the three circuits inside the case.*

*6. Formulas are developed for the calculation of regulation with various loads in the different windings.*

*7. Formulas are developed for the division of load between two primary circuits, or two secondary circuits in parallel.*

*8. Formulas are developed for the equivalent effective impedance for short circuits.*

*9. The behaviour of a three-circuit transformer operating in parallel with a two-circuit transformer is analyzed so as to determine the flow or distribution of load kv-a. in the network.*

*10. The problem of unsymmetrical loads, particularly that of single-phase line-to-neutral short circuits on a polyphase system are discussed in an appendix, with a simplified method of solution, deriving formulas for some representative cases. When the transformer is interconnecting two polyphase generating systems, the division of single-phase line-to-neutral loads and short circuits between the two systems is considered and solved by the same method and formulas.*

*11. The theory of three-circuit transformers is extended to four circuits in another appendix illustrated by an example, and is then generalized to n-circuit transformers.*

*12. For convenient reference, the more important formulas and symbols are collected in another appendix.*

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## The Problem

THREE-circuit transformers present some interesting characteristics, involve a number of new problems and cover a much wider field of application than one might suspect. As examples the following short list of the more important cases may be cited:

Transformers having two primary windings supplying one load from two separate generators or generating systems of different voltages. The systems may be single-phase or polyphase. Problems arise as to, (a) the division of load and short-circuit current between the two primaries, (b) the equivalent effective impedance of the transformer for a short circuit across the secondary lines, and, (c) regulation.

Transformers having one primary winding and two separate secondary windings supplying two separate loads of different voltage ratings. One of the secondaries may be a condenser circuit for power factor correction or voltage regulation or both. The system may be single-phase or polyphase. The main problems are those of regulation and the combined load in the primary.

Transformers having one primary winding, one secondary (load) winding and one tertiary winding, the latter not connected to a load but provided for the purpose of magnetically interlacing the different phases of a polyphase bank, as for instance in the case of four-wire $Y$-$Y$ distribution-transformers and grounded $Y$-$Y$ banks. The problems to be solved are: Regulation for unbalanced loads (line-to-neutral), and equivalent effective impedance for line grounds, that is, for line-to-neutral short circuits.

Transformers with one primary winding, one secondary winding and one voltmeter winding. The main problem is that of regulation, and the object to be attained in design is to make the voltmeter winding indicate the true voltage of the secondary by turn ratio, or, when this condition is not a fact, to know the necessary correction.

Transformers having two primary windings interconnecting two generating systems and one tertiary winding not connected to any load but provided for the purpose of magnetically interlacing different phases of a polyphase bank. The problems are: Equivalent reactance of the bank for line-to-neutral short circuits, and the division of short-circuit current between the two primaries or generating systems.

Transformers of which the primary or the secondary (or both) consist of two or more coils in multiple. The important problem is the division of load current, on account of serious local overheating which may be caused by unbalanced current division. Ordinarily, parallel coils are balanced for normal operation, but tap connections on any winding may introduce an unbalance, or some other feature, such as many-stranded conductors may involve an unbalance that is not objectionable but requires calculation.

A three-winding transformer in multiple with a two-winding transformer. The important problem is the division of load among the various windings and generators.

*Abridgement of a paper presented at the Midwinter Convention of the A. I. E. E., Philadelphia, Pa., February 4-8, 1924. Complete copies available to members on request.*

### Some Peculiar Phenomena

In a two-primary one-secondary transformer, the division of load between the two primaries is not as simple a matter as the usual rule of "inversely as their impedances with respect to the secondary," as one might expect. With certain coil arrangements one primary may carry practically the entire load regardless of the reactance of the other primary with respect to the secondary. And not only that, but simple coil-arrangements are possible in which one of the primaries not only does not carry its share of the secondary load, but itself draws power from the transformer and feeds it to its generator proportional to the secondary load. That generator and prime-mover characteristics affect the load division is of course true and the division of load may be absolutely controlled thereby, as is to be discussed in due order, but the peculiar phenomenon here referred to is one which the characteristics of the transformer windings in certain combinations tend to impose, and holds particularly true if the two generators were on one shaft, or, if the two circuits were connected in multiple to the same busbars.

In certain other cases load division may be indeterminate as far as the reactances of the windings go and be entirely determined by the resistances of the windings. This happens when two primaries are thoroughly interlaced.

In case of a short circuit on the secondary of a transformer which has two independent primary circuits, the total short-circuit current is not necessarily the sum of the short-circuit currents which the two primaries would separately and independently produce.

In a one-primary two-secondary transformer, if one of the secondaries is loaded and the other is idle, the voltage regulation across the idle secondary may or may not be zero and may be positive or negative, *i. e.*, the voltage may be lowered or boosted, depending, as before, on the arrangement of the windings.

A somewhat common illustration of the difference in the regulation of two secondary windings is found in high-voltage testing transformers in which the inaccuracy of obtaining the secondary voltage by ratio from the primary is recognized and a special voltmeter coil is provided. The relative location of this voltmeter coil with respect to the primary and secondary determines the accuracy of the voltage readings taken from it.

### A Function of Impedances

Although the characteristics of a three-circuit transformer are functions of the arrangement of the windings, yet, to be able to predetermine those characteristics, it is not necessary to have a drawing of the physical arrangement of the windings, or, in its absence, to dismantle the transformer to expose it to view. The arrangement and relative position of the windings are important only in their effect on the reactances of the windings for the subject under consideration, and thus, if those reactances (or, rather, impedances) are known, the performance characteristics of the transformer can be completely determined.

In dealing with alternating-current problems, it is unnecessary to go beyond the conceptions of resistance, reactance and impedance (in ohms or in percentages) into those of inductance in henries, capacitance in farads, and differential coefficients of currents and voltages. No recourse is taken to them in this paper, and the equations and formulas are developed in terms of the engineering units of resistance, reactance and impedance.

Furthermore, the reactances considered in this paper refer exclusively to those reactances which the transformer offers to the load currents (not those which apply to the magnetizing currents). They are sometimes called load-reactances and sometimes leakage-reactances. In the present paper all reactances and impedances will be understood to be those applying to the load currents, unless otherwise explicitly excepted.

Most of the characteristics of a three-circuit transformer including the peculiar phenomena mentioned above may be seen by the aid of an equivalent network which may therefore be profitably described at this point.

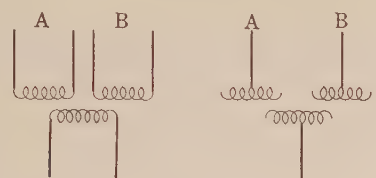
### Equivalent Network of Three-Circuit Transformer

A single phase, three-circuit transformer is shown diagramatically in Fig. 1, as a two-line diagram in Fig. 1 A, as a single-line diagram in Fig. 1 B, with connected apparatus *A*, *B*, *C*, which may be generators, motors, lighting load, or any other kind of electrical apparatus. All that the transformer does between the circuits of *A*, *B* and *C* is to link them with a transformation in voltage and current. This transformation is accomplished at the expense of a magnetizing current taken by the transformer, core and copper losses in the transformer, and an impedance or impedances introduced between the various circuits. In considering such characteristics as regulation, division of load, short-circuit currents, etc., magetizing current may be ignored, and, since the ratio of transformation has no effect on these characteristics, it may be assumed as one-to-one for convenience. If the transformer and load constants are given in ohms, amperes, volts, etc., turn ratios must of course be considered in transferring or converting them from one winding to another.[1] However, if all such quantities be expressed as percentages of rated values of corresponding circuits (based on an assumed standard kv-a. load) turn ratios drop out of consideration completely. Since transformer constants are as a rule given in

1. Currents and voltages are reduced from the basis of one circuit to that of another by the inverse of the turn ratios. Resistances and reactances in ohms are reduced directly by the square of the turn ratios.

percentages, and most answers to problems are required in percentage form, and since also it is very desirable not to encumber equations and calculations by factors involving turn ratios, therefore, in all equations throughout this paper turn ratios are entirely ignored and the various constants are understood to be either per cent or converted values. As a rule, there is less chance of error in calculations if percentages are used rather than the converted values of ohms, volts and amperes.

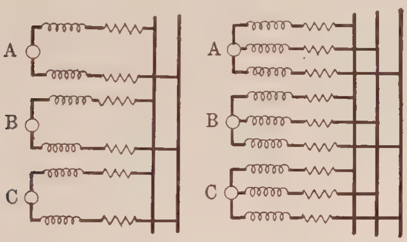
With this understanding, the magnetically interlinked circuits of a three-circuit transformer may be completely represented by the electrically interlinked




(a) Single-phase Two-line Diagram

(b) Single-phase Single-line Diagram

Fig. 1—Diagrammatic Sketch of Three-Circuit Transformer




Figs. 2A and 2B

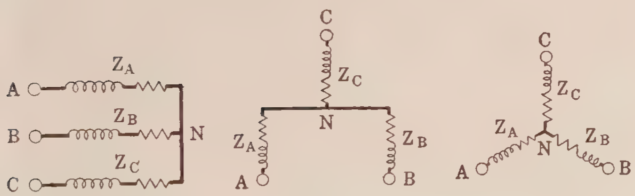



Fig. 3a Fig. 3b Fig. 3c

Figs. 3A, 3B and 3C

circuits of Fig. 2; Fig. 2A representing a single-phase unit (or bank) of three-circuit transformers, and Fig. 2B a three-phase unit (or bank) of three-circuit transformers. Both Figs. 2A and 2B are considerably simplified by the use of a single line diagram as in Fig. 3A. Fig. 3A therefore applies to all single-phase and symmetrical polyphase transformers interconnecting three circuits per phase. Fig. 3B is essentially the same as Fig. 3A but may sometimes be preferred so as to segregate the primary and secondary circuits from each other. Fig. 3C is a perfectly symmetrical diagram and may be preferred by some. It should be carefully noted that Fig. 3C is a connection diagram like the others (not a vector diagram) and that therefore its appearance like a three-phase $Y$ must not lead one to think that the circuits $A$, $B$ and $C$ are 120 deg. away from each other. These three circuits or systems (*i. e.*, $A$, $B$ and $C$) are in phase with each other except for what little phase-shift may be produced by impedance drops due to load currents.

It will be noted that the equivalent network amounts to the connection of the three circuits or systems $A$, $B$ and $C$ to the same busbars through impedances $Z_a$, $Z_b$ and $Z_c$, equivalent to the impedance effect of the interconnecting transformer (or auto transformer). The physical significance of this equivalence will be discussed below.

## Impedances of the Equivalent Network

The impedances $Z_a$, $Z_b$, $Z_c$ of the equivalent network (Fig. 3) are not as a rule equal to each other, and, although they originate in the commonly recognized leakage impedances between pairs of windings of the transformer, they are not numerically equal to them but are determined by them as follows:

It is well-known that power or kilovolt-amperes flowing between a pair of circuits, say $A$ and $B$, interconnected by a transformer must overcome the leakage impedance $Z_{ab}$ introduced by the transformer. Looking at the equivalent network of such a transformer (Fig. 3C), it will be seen that the impedance to the flow of kilovolt-amperes between $A$ and $B$ is $(Z_a + Z_b)$. Hence, if the equivalent network is to represent the performance of the transformer correctly, it must satisfy the condition that,

$$Z_a + Z_b = Z_{ab} \tag{1}$$

Similarly, it must satisfy the conditions that

$$Z_a + Z_c = Z_{ac} \tag{2}$$

$$Z_b + Z_c = Z_{bc} \tag{3}$$

Solving these equations for $Z_a$, $Z_b$ and $Z_c$, which are the impedances of the equivalent network, in terms of $Z_{ab}$, $Z_{ac}$ and $Z_{bc}$ (which are standard data of a transformer) we obtain

$$Z_a = \frac{Z_{ab} + Z_{ac} - Z_{bc}}{2} \tag{4}$$

$$Z_b = \frac{Z_{ab} + Z_{ac} - Z_{ac}}{2} \tag{5}$$

$$Z_c = \frac{Z_{ac} + Z_{bc} - Z_{ab}}{2} \tag{6}$$

These equations are naturally vectorial. The resistance and reactance components of the equivalent impedances are therefore

$$X_a = \frac{X_{ab} + X_{ac} - X_{bc}}{2} \tag{7}$$

$$X_b = \frac{X_{ac} + X_{bc} - X_{ac}}{2} \tag{8}$$

$$X_c = \frac{X_{ac} + X_{bc} - X_{ab}}{2} \qquad (9)$$

$$R_a = \frac{R_{ab} + R_{ac} - R_{bc}}{2} \qquad (10)$$

$$R_b = \frac{R_{ab} + R_{bc} - R_{ac}}{2} \qquad (11)$$

$$R_c = \frac{R_{ac} + R_{bc} - R_{ab}}{2} \qquad (12)$$

In a transformer with three independent windings, $R_a$ is identically the same as the effective $A\ C$ resistance of winding $A$; $R_b$ the same as that of winding $B$; and $R_c$ the same as that of winding $C$. Equations (**10**), (**11**) and (**12**), however, have not been put in merely for their symmetrical looks in comparison with the reactances, but in apparatuses, having considerable stray a-c. impedance-losses the effective a-c. resistance of each winding may be difficult to predetermine while the effective resistance of pairs of windings may be easier to predetermine and still easier to test. In other words, exact values of the equivalent resistances are obtained more accurately from the impedance-watts measurements per pair of windings with the aid of formulas (**10**), (**11**) and (**12**). Furthermore, in auto transformers the windings of the various circuits not being independent of each other, the simplification which applies to straight transformers would not apply to them, while equations (**10**), (**11**) and (**12**) apply universally. Since in any transformer or auto transformer the copper or impedance loss (watts) for any pair of circuits (one acting as primary the other as secondary) is a requisite datum, the convenience and simplicity of these equations may be appreciated.

It may not be amiss to emphasize two considerations at this point:

(a) All impedances used in these equations (whether in ohms or in percentages) must be those effective at the external circuit terminals. In straight transformers there is not much chance of error in this matter (especially if the impedances are expressed as percentages) but in the case of auto transformers there is a possibility of confusing the impedances between series and common windings of the unit as a transformer and the values as auto transformer, in which case the auto transformer values must be used because they are the values effective at the circuit terminals. It is for this reason that throughout this paper the word "circuit" is very frequently used instead of "winding."

(b) If the various impedances are expressed as percentages, they must all be based on a common standard kv-a. output which standard output may be assumed arbitrarily regardless of the capacity of the circuits. The actual kv-a. loads in the various circuits may then be given as certain fractions or multiples of this assumed standard kv-a. output.

## Physical Significance of the Equivalent Impedances

The physical significance of the impedances of the equivalent network may be viewed in two different ways:

*Equivalent Impedances considered as the Effective Impedances of the Individual Windings (or Circuits).* If the total impedance between the windings of two circuits, say $A$ and $B$, is $Z_{ab}$, we may conceive that a portion $Z_a$ of this total impedance $Z_{ab}$ belongs to the winding of circuit $A$, and the rest of it, which we may call $Z_b$, belongs to the winding of circuit $B$, and then of course, as in equation (**1**),

$$Z_a + Z_b = Z_{ab}$$

We have already seen that in a simple case, such as a transformer with three independent windings, the resistance components of the equivalent impedances are identical with the resistances of the corresponding individual windings, and it is therefore most natural to conceive of the reactance components of the equivalent impedances as the reactances of the corresponding individual windings.

This is an extremely simple point of view and therefore very convenient and useful in practical problems.

In a two-circuit transformer the resolution of its total reactance into primary and secondary reactances is indeterminate[2] and unnecessary: unnecessary for the simple reason that the usual operating characteristics of a two-winding transformer depend on the total impedance and not on its division between primary and secondary. In a three-circuit transformer such a resolution becomes necessary and the problem is rendered determinate by the condition that the resolutions of the three total leakage impedances $Z_{ab}$, $Z_{ac}$ and $Z_{bc}$ between corresponding circuits be consistent as formulated by the simultaneous equations (**1**), (**2**) and (**3**), and solved by equations (**4**), (**5**) and (**6**).

The equivalent network, then, instead of dealing directly with the total leakage-impedances between pairs of windings or circuits, deals with the leakage-impedances of the individual windings or circuits.

This point of view is quite simple, and very helpful in attacking problems of regulation, division of load, short-circuit currents, and allied problems, and is valid within the scope of all such problems. It is recommended therefore to all who are interested in practical applications and do not wish to be encumbered by refinements of more rigorous theory. The scope and limitations of this point of view are critically discussed in Appendix A, after which the second interpretation of the equivalent impedances is given considering them as "mutual impedances" effective for load currents. This second point of view is ab-

2. Unless the complete design of the transformers were available.

solutely rigorous and universal but somewhat more difficult to grasp than the first.

### Explanation of the Peculiar Phenomena

A number of the peculiar phenomena mentioned in the foregoing may be explained by an inspection of the equivalent network.

It is possible for one of the reactances in the equivalent network to be negative (See Fig. 4). Equations (**7-9**) do not contradict this possibility, and experience

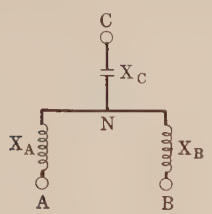



Fig. 4

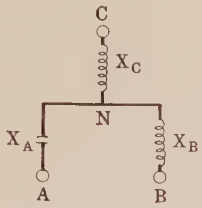



Fig. 5

with concrete transformer designs confirms it. It can be reasoned out, however, that not more than one branch can have a negative reactance, because the net impedance between every pair of windings of the transformer must be positive or inductive and can not be negative or condensive. It also follows from this consideration that the negative reactance must be smaller than either one of the positive reactances in the other branches. As a matter of fact, if a negative reactance occurs, it is very small compared with the other reactances. How a negative or condensive reactance effect can occur in the leakage reactance of the inductive windings of a transformer involves a rather elaborate analysis of leakage flux linkages described in Appendix C. It is this equivalent negative reactance that is responsible for most of the peculiar phenomena mentioned above.

(*a*) *Explanation of Regulation Peculiarities.* Considering Fig. 4, assume that $C$ is a generator, $A$ is an inductive load, and $B$ an idle secondary. Evidently, the voltage of $A$ will drop under its assumed lagging-power-factor load, because the net impedance from $C$ to $A$ is inductive. However, the voltage of $B$ must rise under the lagging-power-factor load of $A$ because the drop in the condensive reactance $X_c$ by a lagging current will boost the voltage at the point $N$, and as there is no current and no drop in $X_b$, the voltage of $B$ will be same as at $N$ and therefore boosted above that of $C$. To state it in a more general way: With a lagging load in either $A$ or $B$ or both, the voltage of the neutral point $N$ will be higher than the impressed voltage at $C$. Thus it may be seen how a given load at a given point may lower the voltage of some part of the network and raise that of another.

(*b*) *Explanation of Short-Circuit Current Peculiarity.* Let $A$ and $B$ in Fig. 3B be two primary circuits, and $C$ the secondary. If the impedance $Z_c$ were zero, the short-circuit current in $C$ furnished jointly by $A$ and $B$ would be the vector sum of the short-circuit currents which $A$ and $B$ would independently produce. However, if $Z_c$ is the dominant impedance of the network, and $Z_a$ and $Z_b$ comparatively negligible, the short-circuit current in $C$ will be practically the same whether $A$ alone or $B$ alone or both are excited.

(*c*) *Explanation of Peculiarities in Load Division.* Let $A$ and $B$ in Fig. 5 be two primary circuits, $A$ with a condensive reactance, $B$ with an inductive reactance. If the secondary $C$ is loaded, evidently $A$ and $B$ will divide the load inversely as the impedances of their respective branches. But the impedances of these two branches have opposite signs, and therefore the currents and kilovolt-amperes in those two circuits will have opposite signs. Thus, if the secondary load is of unity power factor, one of the primary circuits, *viz.*, $A$, will act as generator, the other, $B$, as motor, $A$ furnishing power to both $C$ and $B$. The vector diagram of this is shown in Fig. 6. If the load in $C$ is a zero power factor lagging load, $A$ will furnish a lagging load, $B$ a leading load, the latter being neutralized by the excess lagging load in $A$.

The foregoing peculiarity in load division is rather of theoretical interest only and does not imply a possible source of difficulty in practise, because division of load between two primary circuits can not in practise be left to the peculiarity of the apparatus but is controlled externally: the division of the kw. component of the load is controlled by the setting of the governors of the prime-movers, the division of the reactive component of the load being controlled by the setting of the voltage regulators of the generators or primary circuits, as will be further discussed below. The peculiarity mentioned above could take place only under two different conditions, *viz.*, (a), if the two primary windings $A$ and $B$ were actually connected in multiple, or (b), if the

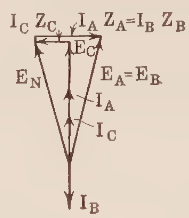



Fig. 6

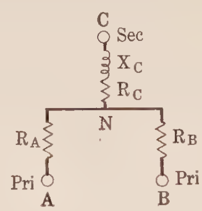



Fig. 7

generators of $A$ and $B$ were mounted on one shaft and their angular position fixed so as to make their voltages in phase in accordance with the vector diagram in Fig. 6 where $E_a$ and $E_b$, the terminal voltages of $A$ and $B$, are shown as identical. This condition of course does not arise ordinarily in practise except in complicated tie-in networks and can even in those cases be controlled completely by means of regulators.

The second peculiarity in load-division, the case in which load-division is independent of the reactances

of $A$ and $B$ with respect to $C$, but is determined by their resistances only, is when the reactances of the branches of $A$ and $B$ is zero, the reactance between the two primaries being zero and that from either primary to the secondary being $X_c$. (Fig. 7.)

With the aid of the foregoing general physical concept of the network of a three-circuit transformer, we are in a position to proceed to the derivation of formulas for the calculation of regulation, load division and short-circuit currents.

### Calculation of Regulation

Regulation may be formulated in a number of ways, some absolute, some approximate. We may first review the regulation formulas for a two-circuit transformer and then indicate how they apply to three-circuit problems.

*Two-Circuit Transformers. (a) Absolute Formulas.*

$$\text{Per Cent Regulation} = \left\{ \frac{E \text{ total}}{E \text{ load}} - 1 \right\} 100 \tag{13a}$$

$$= \left\{ \frac{Z \text{ total}}{Z \text{ load}} - 1 \right\} 100 \tag{14a}$$

$$= \left\{ \frac{\text{kv-a. input}}{\text{kv-a. output}} - 1 \right\} 100 \tag{15a}$$

$$= \left[ \sqrt{\left\{ 1 + m \frac{(\% I R)}{100} + n \frac{(\% I X)}{100} \right\}^2 + \left\{ m \frac{(\% I X)}{100} - n \frac{(\% I R)}{100} \right\}^2} - 1 \right] \times 100 \tag{13b}$$

$$= \left\{ \sqrt{\frac{(R_{load} + R_{trans})^2 + (X_{load} + X_{trans})^2}{R_{load}^2 + X_{load}^2}} - 1 \right\} 100 \tag{14b}$$

$$= \left\{ \sqrt{\left(m + \frac{\% I R}{100}\right)^2 + \left(n + \frac{\% I X}{100}\right)^2} - 1 \right\} 100 \tag{14c}$$

$$= \left\{ \sqrt{\frac{(\text{kw.}_{output} + \text{kw.}_{imp.})^2 + (\text{kv-a}_{react.\,output} + \text{kv-a}_{react.\,imp})^2}{\text{kw.}^2_{output} + \text{kv-a.}^2_{react.\,output}}} - 1 \right\} 100 \tag{15b}$$

*Notes on Absolute Formulas.* In equation (**13a**) the total vóltage is the no-load secondary voltage which also of course corresponds to the no-load primary voltage reduced to the same basis of turns. The total voltage might also be called the input voltage, and the load voltage might be called the output voltage.

Formulas (**14a**) and (**15a**), if not self-evident, can be derived from (**13a**); (**14a**) is derived by *dividing* the numerator and the denominator of the fraction in (**13a**) by the load-current: (**15a**) is derived by *multiplying* the numerator and denominator of the fraction in (**13a**) by the load-current. In (**15a**) the kv-a. input is exclusive of the magnetizing current and the core loss. These are ignored because they do not change from no-load to full-load and do not produce a change in voltage with varying load. Even ignoring the excitation kilovolt-amperes of the transformer, the input kilovolt-amperes is different from the output kilovolt-amperes on account of the kilovolt-amperes consumed in the impedance of the transformer.

Formulas (**13a**), (**14a**) and (**15a**) are basic, and although they are not in terms of commonly given data for direct substitution, they can be expressed in terms of such data as shown in formulas (**13b**) deduced from (**13a**); (**14b**) and (**14c**) deduced from (**14a**); and (**15b**) deduced from (**15a**). In (**14b**) the resistances and reactances are in ohms. In (**15b**) the subscript "imp." designates the kw. or reactive kv-a. consumed in the impedance of the transformer.

Of all these formulas, the simplest, most direct and as a rule, the most convenient one is (**14c**) $m$ is the power-factor of the load and $n$ its reactive factor. All percentages and other variable data must of course correspond to the actual load, otherwise a conversion or correction factor must be included.

The absolute formulas give the regulation as the difference of two numbers which are very nearly equal, and, therefore, to get this difference, *i. e.*, the final answer, correct to two or three significant figures, the value of the square root term must be computed correct to four or five places. Hence, the absolute formulas as such do not yield much accuracy with a ten-inch slide rule, but they are useful for reference, and they also form the basis of all approximate formulas.

Regulation may be positive or negative. Positive regulation corresponds to drop in secondary voltage at full load, or, rise in secondary voltage at no-load as the A. I. E. E. definition puts it. Negative regulation is then rise in voltage at full-load, or drop in voltage at no-load. The A. I. E. E. wording is preferable, one of the many reasons pertinent to the following discussion being that the rise or drop of voltage from full-load to no-load is also the rise or drop of voltage from (loaded) secondary to primary, from output voltage to input voltage. Corresponding to negative regulation, primary or input voltage (per cent or converted value) will be less than secondary or output voltage; the primary or input kilovolt-amperes (exclusive of excitation kilovolt-amperes) will be less than the load or output kilovolt-amperes and the total impedance (*i. e.*, impedance of load plus vectorially the impedance of the transformer) will be less than the load impedance alone.

*Approximate A. I. E. E. Formula.* An approxima-

tion based on formula (**13b**) and standardized by the A. I. E. E. is as follows:[3]

$$\text{Per cent Reg.} = m\,(\text{per cent } I\,R) + n\,(\text{per cent } I\,X) + \frac{[m\,(\text{per cent } I\,X) - n\,(\text{per cent } I\,R)]^2}{200} \quad (\mathbf{16})$$

## Regulation of Three-Circuit Transformers

Since the load of a three-circuit transformer is not likely to be the same in any two of its circuits, the two-circuit regulation formula cannot be applied directly but must be applied in two steps as is to be described below.

Just as in a three-circuit transformer with two secondary circuits the regulation in the two secondaries need not be alike, so, in a transformer with two primary circuits, if the share of each primary from the total load is to be externally controlled, then, the two primary circuits will have to have different voltages at full load than on no load. Therefore, in a three-circuit transformer there are three regulations to be considered corresponding to the three pairs of windings or circuits.

Referring to Fig. 3B, the regulation between $A$ and $C$ may be calculated in two steps: From $A$ to $N$ (the neutral), and from $N$ to $C$. Then, designating the first $\text{Reg}_{an}$ and the latter by $\text{Reg}_{nc}$, the regulation, $\text{Reg}_{ac}$, between $A$ and $C$ is,

$$\text{Per Cent Reg}_{ac} = \text{Per Cent Reg}_{an} + \text{Per Cent Reg}_{nc} \quad (\mathbf{16a})$$

$$= \text{Per Cent Reg}_{an} - \text{Per Cent Reg}_{cn} \quad (\mathbf{16b})$$

The correctness of this procedure will be recognized considering the fact that regulation is not a vector concept but an algebraic one. It can only be positive or negative; one representing drop in voltage, the other rise in voltage. Regulation between two points (or circuits) can therefore be calculated as the algebraic sum of two steps; one from the first point to an intermediate point, and the second, from that intermediate point to the final point, these points and the direction being indicated by the subscripts. Accordingly, if per cent $\text{Reg.}_{an}$ is positive, per cent $\text{Reg.}_{na}$ must be considered negative, since, if the voltage rises from $A$ to $N$, it must drop from $N$ to $A$. That is the basis of the difference between (**16b**) and (**16a**) which differ in the order of the subscripts of the second term, the two forms being given to emphasize the algebraic character of the formula. However, it is believed that no error is likely to be made in practise due to confusion of signs if the physical facts are clearly kept in sight. As a convenient rule we can say that if two circuits are dissimilar in duty, that is, one is primary, the other secondary, the regulation between them is the algebraic sum of the regulation from the secondary to the neutral and the regulation from the neutral to the primary (eq. **16a**); but if both are primary or both secondary, then, the regulation between them is the algebraic difference of their regulations with respect to the neutral point (eq. **16b**).[4]

*Example.* A three-phase bank of three 5000-kv-a. transformers interconnects a 66,000-volt generating system, a 114,000-volt transmission system and a 13,860-volt synchronous condenser load. The 66,000 volts are stepped up to 114,000 volts through a single winding, that is, through an auto transformer, but that does not in any way influence the calculation of regulation once the impedances effective at the external circuit terminals are known.

*Data.* The following data are by test, and all the percentages are based on an output of 5000 kv-a. per phase.

Per Cent $I\,R_{PS} = 0.55$; Per Cent $I\,R_{PT} = 0.60$;
Per Cent $I\,R_{ST} = 0.50$
Per Cent $I\,X_{PS} = 8.65$; Per Cent $I\,X_{PT} = 10.6$;
Per Cent $I\,X_{ST} = 8.3$

From these data the impedances of the individual circuits are calculated to be,

$$\text{Per cent } I\,R_P = \frac{\text{per cent } I\,R_{PS} + \text{per cent } I\,R_{PT} - \text{per cent } I\,R_{ST}}{2} = 0.325$$

$$\text{Per cent } I\,R_S = \frac{\text{per cent } I\,R_{PS} + \text{per cent } I\,R_{TS} - \text{per cent } I\,R_{PT}}{2} = 0.225$$

$$\text{Per cent } I\,R_T = \frac{\text{per cent } I\,R_{PT} + \text{per cent } I\,R_{ST} - \text{per cent } I\,R_{PS}}{2} = 0.275$$

$$\text{Per cent } I\,X_P = \frac{\text{per cent } I\,X_{PS} + \text{per cent } I\,X_{PT} - \text{per cent } I\,X_{ST}}{2} = 5.475$$

$$\text{Per cent } I\,X_S = \frac{\text{per cent } I\,X_{PS} + \text{per cent } I\,X_{TS} - \text{per cent } I\,X_{PT}}{2} = 3.175$$

$$\text{Per cent } I\,X_T = \frac{\text{per cent } I\,X_{PT} + \text{per cent } I\,X_{ST} - \text{per cent } I\,X_{PS}}{2} = 5.125$$

The equivalent network of this transformer together with the numerical values of its constants are shown in Fig. 8 which should be kept in view in the following calculations.

3. A. I. E. E. standardization Rule No. 6391-b. We have written out above as per cent $I\,R$ the meaning of "$q_r$" and as per cent $I\,X$ the meaning of "$q_x$" used in the A. I. E. E. formula.

4. Regulation of a three-circuit transformer may be calculated correctly by at least three different methods. The scheme of referring all regulations to the meutral point was suggested by Mr. K. K. Palueff. Another method is given in Appendix F.

To calculate the various regulations for the following conditions of load:

Circuit $S$ delivering 5000 kv-a. at 80 per cent lagging power factor

Circuit $T$ delivering 2900 kv-a. at 0 per cent leading power factor.

The regulation from the secondary to the point $N$ by the A. I. E. E. formula (equation (**16**) is

$$\text{Per cent Reg}_{SN} = 0.80 \times 0.225 + 0.60 \times 3.175 + \frac{(0.80 \times 3.175 - 0.60 \times .225)^2}{200} = +2.11$$

In calculating the regulation from the terminals of the tertiary circuit $T$ to the point $N$, we must note that the actual load (2900 kv-a.) is less than the standard load (5000 kv-a.) on which the percentage values of the impedances of its branch are based. The latter should therefore be reduced by the ratio ($2900/5000 = 0.58$) in the calculation of regulation which will be

$$\text{Per Cent Reg}_{TN} = 0 \times 0.58 \times 0.275 - 1 \times 0.58 \times 5.125 + \frac{(0 + 1 \times 0.58 \times 0.275)^2}{200} = -2.97$$

In calculating the regulation from the point $N$ to the terminals of primary $P$ we must first calculate the actual load in that branch.

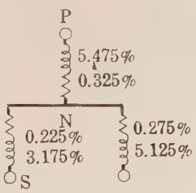


FIG. 8

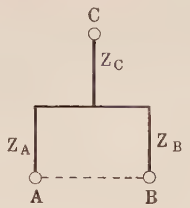


FIG. 9

Evidently, the output of the branch $P$ is the vector sum of the following four items, *viz.,* (a) kv-a. in the external load of circuit $C$, (b), kv-a. in the external load of circuit $T$, (c) kv-a. consumed in the impedance of branch $S$, (d), kv-a. consumed in the impedance of branch $T$. Making this calculation in tabular form, we have,

Output of Circuit $P$ per Phase

| | Kw. | Kv-a. Reactive |
|---|---|---|
| Output of $S$ | 0.80×5000 | +0.60×5000 |
| Output of $T$ | 0 | − 2900 |
| Impedance kv-a. of $S$ | 0.00225×5000 | +0.03175×5000 |
| Impedance kv-a. of $T$ | 0.00275×.58×2900 | +0.05125×0.58×2900 |
| Total | 4016 kw. | +345 kv-a. lagging |

4030.79 kv-a. at 99.63 per cent power factor
8.56 per cent reactive factor

The percentage values of the impedances of branch $P$ are based on an output of 5000 kv-a. per phase, but since the actual output is 4030.79 kv-a. the actual percentages will be ($4030.79/5000 = 0.807$) times the values given in Fig. 8.

The input of circuit $P$ (exclusive of excitation kv-a.) will be the vector sum of its output and the kv-a. consumed in the impedance of branch $P$. Thus,

Input of Circuit $P$

| | Kw. | Kv-a. Reactive |
|---|---|---|
| Output | +4016 | +345 |
| Impedance | +0.00325×0.807×4030.8 | 0.05475×0.807×4030.8 |
| Total | 4026.55 | +523 lagging |

4060.37 kv-a. at
99.17 per cent power factor
12.88 reactive factor

Since we know the input and output of branch $P$, we could calculate the regulation from $N$ to $P$ by formula (**15a**) as an illustration:

$$\text{Per cent Reg}_{NP} = \left\{ \frac{4060.37}{4030.79} - 1 \right\} \times 100$$

$$= \left\{ \frac{4060.37 - 4030.79}{4030.79} \right\} \times 100$$

$$= 0.734$$

The regulations between pairs of circuits then follow as

$$\begin{aligned}
\text{Per cent Reg}_{SP} &= \text{Per cent Reg}_{SN} + \text{Per cent Reg}_{NP} \\
&= 2.11 + 0.734 = +2.84 \\
\text{Per cent Reg}_{TP} &= \text{Per cent Reg}_{TN} + \text{Per cent Reg}_{NP} \\
&= -2.97 + 0.734 = -2.24 \\
\text{Per cent Reg}_{ST} &= \text{Per cent Reg}_{SP} - \text{Per cent Reg}_{TP} \\
&= +2.84 - (-2.24) = +5.08 \\
\text{or} \quad &= \text{Per cent Reg}_{SN} - \text{Per cent Reg}_{TN} \\
&= +2.11 - (-2.97) = +5.08
\end{aligned}$$

## DIVISION OF KV-A. LOAD

In a double-secondary transformer of which both secondary windings have the same voltage rating and are actually connected in parallel, also in a double-primary transformer in which the division of the kv-a. load between the two primary circuits is not externally controlled, the division of load will obviously be inversely as the impedances of the respective circuits. Thus, if $A$ and $B$ are those two circuits, (Fig. 3B).

$$\frac{(\text{kv-a.})_A}{(\text{kv-a.})_B} = Z_B / Z_A \tag{18}$$

Since the load in the third circuit $C$ must be the vector sum of those in $A$ and $B$, therefore,

$$\frac{(\text{kv-a.})_A}{(\text{kv-a.})_C} = \frac{(\text{kv-a.})_A}{(\text{kv-a.})_A + (\text{kv-a.})_B}$$

$$= \frac{Z_B}{Z_A + Z_B} = Z_B \, Z_{AB} \tag{19}$$

$$\frac{(\text{kv-a.})_B}{(\text{kv-a.})_C} = \frac{(\text{kv-a.})_B}{(\text{kv-a.})_A + (\text{kv-a.})_B}$$

$$= \frac{Z_A}{Z_A + Z_B} = Z_B/Z_{AB} \quad \textbf{(20)}$$

The two simplified equations, *viz.*:

$$\frac{(\text{kv-a.})_A}{(\text{kv-a.})\ \text{total}} = Z_B/Z_{AB} \quad \textbf{(21)}$$

$$\frac{(\text{kv-a.})_B}{(\text{kv-a.})\ \text{total}} = Z_A/Z_{AB} \quad \textbf{(22)}$$

hold numerically as well as vectorially and are therefore very convenient.[5]

It may appear as though, since in a double-primary transformer load division must be externally controlled, and in a double-secondary transformer the two circuits are usally connected to independent external loads, that these load division formulas have no practical application. We may therefore indicate here some practical applications for them.

(a) In a double primary transformer in case of a short circuit on the secondary side, the division of short-circuit kv-a. between the two primary circuits follows the foregoing formulas at least initially, because control apparatus can not come into play instantly, and, even after they have come into play, they can not function half as effectively under short circuit as at normal loads.

(b) In some complicated interconnections of systems and apparatus, external control though possible is not resorted to on account of increased complication, in which case division of load takes place along the lines indicated above. An illustration of this is afforded in the case of a three-circuit transformer operating in parallel with a two-circuit transformer to be discussed at a later point.

(c) Transformers with only two external circuits will sometimes have two or more circuits in parallel internally. In such cases the parallel circuits are as a rule designed with as perfect symmetry as possible but exceptional cases of dissymmetry may arise in which these formulas will be needed to determine the load taken by each circuit. Eddy current or circulating current problems in some circuits subject to large losses due to such causes incapable of a simple exact theoretical calculation may be approximated by the foregoing formulas.

5. The term (kv-a.) total here means the total output of the two circuits or the input of the third circuit. The input of each primary circuit is its share of this total kv-a. plus (vectorially) the kv-a. consumed in its branch. This qualification is mentioned here to make the principle clear but in many practical cases such refinements of calculation may be unnecessary and the kv-a. consumed inside the transformer may be ignored except in high impedance transformers.

### Short Circuit Impedance

In a one-primary two-secondary transformer, the impedance of the unit for a short circuit across either secondary (one at a time) is of course the same as that of a two-circuit transformer, since one of the secondaries is assumed not to take part in the short circuit. However, in a two-primary transformer, both circuits being excited, also in a two-secondary transformer having a simultaneous short-circuit across both circuits, the effective impedance of the unit in limiting the short circuit is calculated as follows: Designating the two circuits similar in function as $A$ and $B$ (See Fig. 9), and considering them as though they were connected in parallel as shown by the dotted line in the figure, the effective impedance from combined ($A\ B$) to $C$ is evidently

$$Z_{short} = \frac{1}{1/Z_A + 1/Z_B} + Z_C \quad \textbf{(23a)}$$

$$= \frac{Z_{AC}\, Z_{BC} - Z_C^2}{Z_{AB}} \quad \textbf{(23b)}$$

Since in short-circuit problems the resistance of the circuits may in practise be ignored, we may write for the short-circuit reactance of the unit,

$$X_{short} = \frac{X_{AC}\, X_{BC} - X_C^2}{X_{AB}} \quad \textbf{(24)}$$

The share of each one of the two similar circuits of the short-circuit current (or rather kv-a.) follows in accordance with the division of load formulas (equations **21** and **22**).

*Example.* In the example given for regulation, assume that the secondary and tertiary circuits were simultaneously short-circuited. What would be the short-circuit loads in the primary, secondary and tertiary? Calling the secondary $A$, the tertiary $B$, and the primary $C$, we have the constants,

$X_{AC} = 8.65$ per cent; $X_{BC} = 10.6$ per cent;
$X_{AB} = 8.3$ per cent
$X_A = 3.175$ per cent; $X_B = 5.125$ per cent;
$X_C = 5.475$ per cent

Substituting these in equation (**24**),

$$X_{short} = \frac{8.65 \times 10.6 - 5.475^2}{8.3} = 7.43 \text{ per cent}$$

(approx.)

The short-circuit current and kv-a. will therefore be (100/7.43) that is, 13.5 times normal.

The share of the secondary $A$ and tertiary $B$ of this short circuit will be, by formulas (**21**) and (**22**),

$A$'s share $= Z_P/Z_{AB} \times 13.5 \times$ normal
$= 8.35 \times$ normal (approx.)
$B$'s share $= Z_A/Z_{AB} \times 13.5 \times$ normal
$= 5.15 \times$ normal (approx.)

Since the normal, that is, the kv-a. base, is 5000

kv-a., the short-circuit kv-a. in the different circuits will be,

$C$ (primary), $13.5 \times 5000 = 67{,}500$ kv-a. per phase
$A$ (secondary), $8.35 \times 5000 = 41{,}700$ " " "
$B$ (tertiary), $5.15 \times 5000 = 25{,}800$ " " "

The short-circuit currents are calculated similar to the short-circuit kv-a., with this difference, however, that the normal or basic current is not the same for all three circuits on account of their different voltage ratings. The short-circuit currents may also be derived from the short-circuit kv-a.

## Three-Circuit Transformer in Parallel with a Two-Circuit Transformer

Fig. 10 shows a three-circuit transformer with primary $C$, and secondary circuits $A$ and $B$, in parallel with a two-circuit transformer with primary $M$ and secondary $N$, the parallel connection being between primaries $C$ and $M$, and between secondaries $B$ and $N$.

Considering the load on the bus $B\,N$, it is evident that this will be furnished over two paths in parallel (shown by solid arrows), one path with the impedance $(Z_c + Z_b)$, the other with the impedance $Z_{mn}$; the

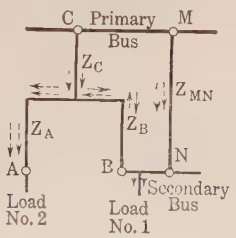



Fig. 10

load dividing between these two paths inversely as their impedances.

Considering the load in $A$, it is evident that this also will be furnished over two paths in parallel (shown by dotted arrows), one path with the impedance $Z_c$, the other with the impedance $(Z_{mn} + Z_b)$; the load dividing between these two paths inversely as their impedances.

In branches $C$, $M$ and $N$, the two component loads add vectorially as shown by the relative directions of the solid and dotted arrows. In branch $B$, link $Z_b$, they subtract vectorially. As a consequence of this, we have the seemingly absurd condition that, assuming the load 1 and 2 to have the same kind of power factor (*i. e.*, both lagging or both leading), the removal of one of the loads increases the load in $B$. The reason for this is, of course, the fact that $B$ acts like a secondary for load 1, but as a primary for load 2.

An interesting feature to observe in this connection is that for a load in $A$ the circuits of $C$ and $B$ acting like two primaries in parallel, the division of load between them is completely determined by the impedances of the network as indicated above, independent of generator and prime mover control apparatus. If desired, it would be possible of course to control this by suitable regulators between $B$ and $N$, or, between $C$ and bus $C\,M$, or between $M$ and bus $C\,M$.

The foregoing considerations show that the planning design and operation of three-circuit transformers in parallel with two-circuit transformers is a much more involved problem than the parallel operation of two-circuit transformers.

*Example.* Let the three-circuit transformer be the same as that used in the previous illustrations. (See also Fig. 8.). Let the reactance $Z_{mn}$ of the two-circuit transformer be 6 per cent. Ignoring the resistances to a first approximation, we have for the constants of the network shown in Fig. 10,

$$X_a = 3.175 \text{ per cent}$$
$$X_b = 5.125 \text{ per cent}$$
$$X_c = 5.475 \text{ per cent}$$
$$X_{mn} = 6 \text{ per cent}$$

Let the load on bus $B - N$ be designated (kv-a.)$_1$ and that on $A$, (kv-a.)$_2$.

$$B\text{'s share of (kv-a.)}_1 = + \frac{Z_{mn}}{Z_{bc} + Z_{mn}} \text{(kv-a.)}_1 = + 0.36 \text{ (kv-a.)}_1$$

$$\text{" " " (kv-a.)}_2 = - \frac{Z_c}{Z_c + Z_b + Z_{mn}} = - 0.33 \text{ (kv-a.)}_2$$

$$\text{" total load} = 0.36 \text{ (kv-a.)}_1 - 0.33 \text{ (kv-a.)}_2 \text{ (vectorially)}$$

$$C\text{'s share of (kv-a.)}_1 = B\text{'s share of (kv-a.)}_1 = 0.36 \text{ (kv-a.)}_1$$

$$\text{" " " (kv-a.)}_2 = \frac{Z_b + Z_{mn}}{Z_c + Z_b + Z_{mn}} \text{(kv-a.)}_2 = 0.67 \text{ (kv-a.)}_2$$

$$\text{" total net load} = 0.36 \text{ (kv-a.)}_1 + 0.67 \text{ (kv-a.)}_2 \text{ (vectorially)}$$

$$M\,N\text{'s share of (kv-a.)}_1 = \text{(kv-a.)}_1 - B\text{'s share} = 0.64 \text{ (kv-a.)}_1$$

$$\text{" " " (kv-a.)}_2 = \text{same as } B\text{'s share but positive} = 0.33 \text{ (kv-a.)}_2$$

$$\text{" total net load} = 0.64 \text{ (kv-a.)}_1 + 0.33 \text{ (kv-a.)}_2 \text{ (vectorially)}$$

$$A\text{'s total net load} = \text{(kv-a.)}_2$$

When very precise results are desired, especially if the reactances are low and the resistances are appreciable, the actual impedances should be used in such calculations (instead of merely reactances), and their manipulation will be vectorial.

When the three-circuit transformer operating in parallel with a two-circuit transformer has two primary circuits instead of two secondary circuits, the general

scheme of analysis is very similar to the foregoing and will be evident in the light of it. Loads 1 and 2 will correspond to generators 1 and 2, respectively, and in most practical cases the load taken up by the two generators will be governed by external control in which case the problem is much simpler than the case discussed in the foregoing in which $(\text{kv-a.})_1$ and $(\text{kv-a.})_2$ were not assumed to have any constant relationship to each other.

### Influence of Generator and Prime-Mover Characteristics

A generator may influence the operation of a three-circuit transformer to which it is connected, by virtue of its impedance and by the action of its voltage regulator.

If the generator is equipped with an automatic voltage regulator, the generator impedance will not influence either regulation or load-division, but it will influence the short-circuit currents and should therefore be included in the impedance of the circuit to which it is connected. That is, in the calculation of the effective short-circuit impedance, also in the division of short-circuit current,

$Z_a$ is to include also the impedance of the generator connected to $A$;

$Z_b$ is to include also the impedance of the generator connected to $B$, etc.

Of course, if the generators are not equipped with any voltage regulators, the modified values of $Z_a$, $Z_b$ and $Z_c$ as defined in the preceding paragraph apply in the calculation of regulation, and also in that of division of load if it is not otherwise externally controlled.

If the induced voltages of two alternators connected in parallel have the same phase-angle but different magnitudes (a condition which may be brought about by the manipulation of the voltage control of the alternators) their difference, the unbalanced voltage, produces a circulating quadrature current through the impedance of the alternators which is practically all reactive. This circulating current is lagging in one and leading in the other unit. If the two induced voltages are equal in magnitude but out of phase from each other (a condition which may be brought about by the manipulation of the governors of the prime-movers) their difference, the unbalance voltage, is in quadrature with their mean value, and produces a circulating current parallel to the mean voltage. This current acts like a generator or load current in one and as motor or power current in the other. Now, if the two alternators are furnishing kv-a. to an external load, it will be evident that the circulating kv-a. load will add (vectorially) to the share of one unit in the external load, and will subtract (vectorially) from the share of the other unit in the external load. The foregoing statements hold whether the alternators are paralleled directly or through transformers. Three conclusions follow from these considerations:

(a) The total net reactive load in one of the two alternators or primary circuits can be increased or decreased at the expense of the other by producing a circulating reactive kv-a. by the manipulation of their induced voltages.

(b) The total net kw. load in one of the two alternators or primary circuits can be increased or decreased at the expense of the other by producing a circulating power by the manipulation of the governors of the prime-movers.

(c) The share of each alternator or primary circuit in the external load is completely determined by the inverse of the impedances of their respective circuits and this is not really altered by either alternator-voltage or prime-mover governor control. These controls merely superpose a circulating kv-a. so as to bring about a desired resultant load in each unit. This superposed circulating kv-a. becomes apparent when the external load is removed; therefore, the resolution of the total load in either circuit into two components as circulating kv-a. and as its share of the external load is not a mathematical fiction but a statement of actual fact.

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## RADIO INDUSTRY IN GREAT BRITAIN

Use of radiotelephony is increasing steadily in Great Britain, where at present there are about 580,000 licensed "listeners in." A large majority of these people own crystal sets, which can be used with good results since broadcasting stations are located in the populous districts throughout the country. There is, however, a good demand for tube sets.

The British manufacturers' interest is principally in expensive sets, but parts are sold to holders of constructors' licenses. These licenses contain a statement, which the licensee must sign, to the effect that he will not knowingly buy any parts of foreign manufacture. The matter is then left open for evasion where nothing is said either by the purchaser or the dealer selling to him as to the origin of parts. Considerable import business in radio apparatus is being done in view of the existing situation.

At the end of 1924 the Postmaster General has the power to change the terms of the licensing system. It is hoped that provision will then be made for a simple general license without any statement as to the source of the set or any of its component parts.

Speaking generally, broadcasting in Britain has had a steady and sound development. The British industry has so far done a good business in the manufacture of equipment. Importers have found their way somewhat obstructed by the general uncertainty relative to the demand from persons taking out constructor's licenses, but use of imported goods has increased along with the general improvement in the trade.

# Three-Phase Wattmeter Connections

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FOR the past 15 years or more there have occured recurrently in technical literature articles giving methods of checking the connections of three-phase wattmeters. In February 1916 Prof. W. B. Kouwenhoven presented a long and detailed paper to the American Institute on the subject. (Vol. 35, Part I, page 183). Practically all these writings point out the frequency with which misconnections occur and their difficulty of detection. In fact this constant recurrence of the subject itself vouches for its importance but it might seem, particularly after Prof. Kouwenhoven's treatment, that another discussion of the subject would be a little superfluous. The writer feels, however, that this is not the case for the reason that all of the existing discussions of the subject which have come to his notice are either incomplete or contain serious errors.

In his extensive treatment of the subject referred to above Prof. Kouwenhoven gives as a complete and sufficient check the interchange of voltage leads 1 and 2 when, he says, if the meter were correctly connected it would stop, if not correctly connected it would continue to run in a certain manner. He makes this statement unqualifiedly for class A meters (meters having four voltage leads brought to it) and qualifies it for class B meters (meters having only three voltage leads) by saying it is true only if phase three is connected to the proper terminal.

When potential transformers are used with class A connections, as they practically always are, if the two leads of the same potential are not tied together the meter is bound to stop, whether the meter were correctly connected or not, when leads 1 and 2 are interchanged as the potential circuits would both be open and no current would flow, while, on the other hand, if the two voltage leads of the same potential are tied together the result is essentially a class B connection so that the test would apply only under the assumption that phase three is connected to the proper terminal.

Moreover for class B meters the test is not certain unless the additional assumption is made that the current phases are correct. In fact the only thing this check really tests for is a reversal of phase in a meter otherwise connected correctly. It is these considerations that lead the writer to offer the following basic treatment which he originally developed while in South America in 1913 but has recently rearranged and simplified.

By a basic treatment is meant one based on the fundamental grounds of a three-phase circuit and two single-phase meters,—nothing else. In this way all assumptions as to type of meter or manner of connection are avoided. With such a basic treatment available it would be very easy for anyone using certain special types of meter to use the particular checks that might be simplest under his conditions.

It might be well to summarize here the conclusions reached that in general no check is possible unless the power factor is known within certain limitations mentioned later. There is a recurring symmetry of values which inherently precludes a decisive conclusion.

The indication of a single-phase meter and thus of each element of a three-phase meter is proportional to $V\, I \cos\phi$ where $\phi$ is the angle of phase displacement between the $V$ and $I$. Dealing as we are with a balanced system the $V$'s and $I$'s for all phases are equal and thus with a different proportionality constant the indications of each element are proportional to the cosine of the phase angle between the $V$ and $I$ brought to that element.

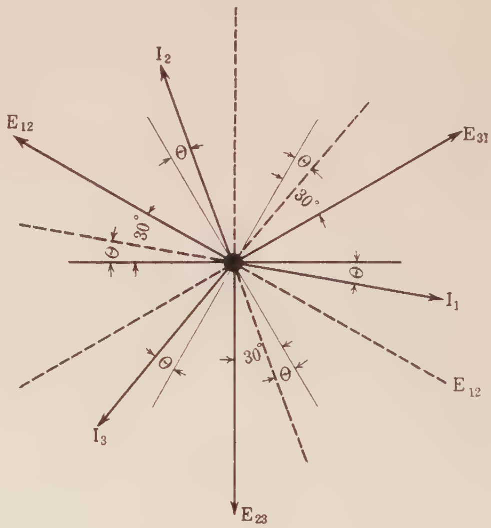


FIG. 1

Fig. 1 shows the phase relations of a balanced three-phase system where $I_1$, $I_2$, and $I_3$, are the line currents and $E_{12}$, $E_{23}$, and $E_{31}$, are the line potential differences. The reverse of each current and potential phase is drawn in dotted lines and the phase positions of the $Y$ voltages, which are also those of the current at unity power factor, are shown in fine lines. $\theta$ is the power factor angle and in Fig. 1 is shown lagging. The phase relations between the three voltages and currents may be now readily determined. Between $E_{12}$ and $I_1$, it is $(30 - \theta)$ but here either the $E$ or $I$ has to be reversed. Between $E_{12}$ and $I_2$ the angle is $(30 + \theta)$ and between $E_{12}$ and $I_3$ is $(90 - \theta)$. Owing to the symmetry of the system the phase angles between $E_{23}$ and $I_2$, $I_3$, and $I_1$ and between $E_{31}$ and $I_3$, $I_1$, and $I_2$, are identical with those already determined between $E_{12}$ and $I_1$,

$I_2$, and $I_3$ being in each case $(30 - \theta)$, $(30 + \theta)$, and $(90 - \theta)$. Thus the only phase angles possible between line potential differences and currents in a balanced three-phase system are these three.

With this information before us it becomes evident that, regardless of the number of leads brought to the meter, 5, 6, 7, or 8 as the case may be, and barring all assumptions as to how these leads may be connected either at the meter or at the instrument transformers (with one exception which will be disposed of later) the only means of getting a check on the correctness of the meter connections is by being able to differentiate between these three cosines.

With three possible cosines for each of the component elements there are just six different combinations for the three-phase meter as a whole; three where the two elements indicate differently and three where they indicate alike. As a corollary to this it follows that there are just six possible different connections of a three-phase meter—one of which is correct and the other five of which are wrong.

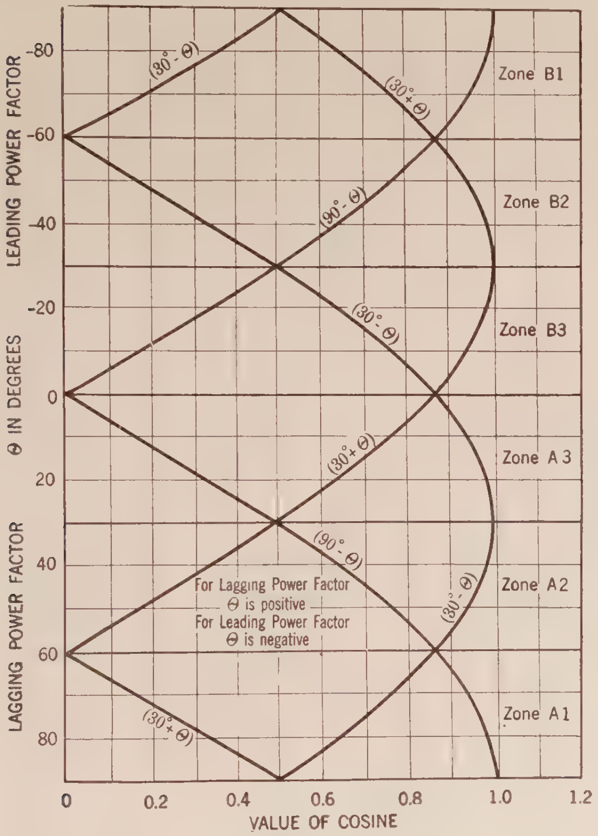

Fig. 2

If we now plot the values of these three possible cosines for all values of $\theta$ from zero lagging power factor to zero leading we have the graphs shown on Fig. 2 where the ordinates are values of $\theta$ and the abscissas are values of the cos $\theta$. This graph has been divided into six horizontal zones each 30 deg. wide and it will be observed that in each zone the curves are identical, although half of the zones are upside down compared to the other three.

Using the zone numbers on the graph where $A$ stands for zones in lagging power factor and $B$ in leading power factor it will be seen that the curves in $A$ 1, $A$ 3, and $B$ 2 are identical but that the cosine expression for the curve in any one position is different for each zone. Thus the cosine which starts from 0.5 and increases to 0.866 in zone $A$ 1 is $(30 - \theta)$, in $A$ 3 is $(30 + \theta)$, and in $B$ 2 is $(90 - \theta)$. The curves of the other three zones, $A$ 2, $B$ 1 and $B$ 3 are exactly similar to the first three, except that the values increase instead of decrease or vice versa as we go up the graph, and again the cosine expressions for the same relative positions are different.

From this graph it is evident that in the total range of power factor there are six positions which will be indistinguishable, judged from the values of the cosines. This at once suggests that we may find our problem unsolvable unless the power factor can be located to within one of these zones.

With this insight into the fundamentals of the problem let us return to the more concrete details of number of leads and possible connections to see the number of possible connections which can be derived when the problem is approached from this side.

The same bases for treatment will be used: First, a balanced three phase system and second, two potential and two current phases brought out to the meter. These two phases may be brought out by either three or four leads each as the number of leads is a detail that may be considered later. The first step is to determine all possible combinations of these phases.

Since there are only two current phases brought to the meter we may call them $I_2$ and $I_3$ respectively. As the phases are equally spaced (120 deg. apart) and each similarly related to three potential phases it makes no difference which particular current phases we assume we have. If we write in a column all the possible combinations of phases for one of the component elements the column at the left in Table I is obtained. Across the top of Table I are the same combinations for the other component element. Thus each intersection of a column and a line gives a combination for the meter as a whole,—36 in all.

TABLE I

| | $E_{12}\ I_2$ | $E_{23}\ I_2$ | $E_{31}\ I_2$ | $E_{12}\ I_3$ | $E_{23}\ I_3$ | $E_{31}\ I_3$ |
|---|---|---|---|---|---|---|
| $E_{12}\ I_2$ | O | | | | | |
| $E_{23}\ I_2$ | O | O | | | | |
| $E_{31}\ I_2$ | O | O | O | | | |
| $E_{12}\ I_3$ | O | X | X | O | | |
| $E_{23}\ I_3$ | X | O | X | O | O | |
| $E_{31}\ I_3$ | X | X | O | O | O | O |

Many of these need not be considered, however. The whole upper right hand half is a duplication of the lower left hand half. These squares of intersection have been left blank. Squares with circles in them have the same potential or current phase or both on each component element. This is, of course, so readily detectable that we need not consider it as to get it one or two of the three or four potential or current leads brought to the meter would be unused. This leaves only six squares (with crosses in them) which are really

different combinations. With these six combinations and the help of Fig. 1 the six possible groups tabulated below Table II are possible. The negative sign before four of the elements indicates that those elements would register in the negative direction and to correct this the potential phase should be reversed giving $E_{13}$ instead of $E_{31}$ for example. It will be here noticed that these groups are the six possibilities we discovered before. Groups 1, 2 and 3 being those where each element indicates differently and groups 4, 5 and 6 those where they indicate alike.

TABLE II

| | | | |
|---|---|---|---|
| Group 1. | $E_{12}\ I_2 \cos (30 + \theta)$ | Group 4. | $E_{31}\ I_2 \cos (90 - \theta)$ |
| | $-E_{31}\ I_3 \cos (30 - \theta)$ | | $E_{12}\ I_3 \cos (90 - \theta)$ |
| Group 2. | $-E_{23}\ I_2 \cos (30 - \theta)$ | Group 5. | $E_{12}\ I_2 \cos (30 + \theta)$ |
| | $E_{12}\ I_3 \cos (90 - \theta)$ | | $E_{23}\ I_3 \cos (30 + \theta)$ |
| Group 3. | $E_{31}\ I_2 \cos (90 - \theta)$ | Group 6. | $-E_{23}\ I_2 \cos (30 - \theta)$ |
| | $E_{23}\ I_3 \cos (30 + \theta)$ | | $-E_{31}\ I_3 \cos (30 - \theta)$ |

There is yet one more side of the problem to be examined before we can start our synthesis which will bring together the various elements into some simple test. The problem which now faces us is a practical one. Having a three-phase meter that we want to check as to connections, and having an insight into the fundamental possible relations between phases, what may we do to the meter leads to discover which particular combination of the six possible ones exists in the meter before us.

Obviously we may note the disk velocity of each element separately by disconnecting the potential lead of the other element. As we are making no assumption that we know the current flowing or the power factor we cannot use absolute values but are forced to use ratios only. From a reading of each element separately only one ratio is possible which is evidently not enough. Referring to Fig. 2 it is evident that the same ratio might exist between either of two combinations in each of the six zones making a total of 12 possibilities.

One other simple thing we can do is to interchange the potential leads, putting the leads that are now on one element—$A$—onto the other element—$B$—and vice versa. If only three leads are brought out or if two of the four are tied together at the meter this is most readily done by interchanging the two leads that are not tied together.

Turning now for a moment to Groups 4, 5 and 6, a brief study will show that they are the same as Groups 1, 2 and 3, respectively, as far as the leads are concerned, with just this change: The potential phases interchanged. It is therefore evident that when we interchange the potential leads each element will run at the same velocity but that in general this velocity will be different from that of each of the two original component elements because the cosine expression is different.

Interchanging the potential leads will therefore give us two more ratios: Those of each of the original velocities to the new one. Between three different things there are possible only three different ratios (other than one to one) and as we have already discovered that there are only three possible cosine expressions, and as we have obtained three ratios by an interchange of potential leads it becomes evident that we have all the information obtainable.

Further study however will show that three ratios are more than we need. By a study of Fig. 2 it will be seen that in order to fix the group of connections only two ratios are needed; the third giving no additional information. Due to the similarity already referred to between the six zones we need confine our attention to one only. Take zone $A$ 2 for example. Suppose we have a meter and note the velocity of each element

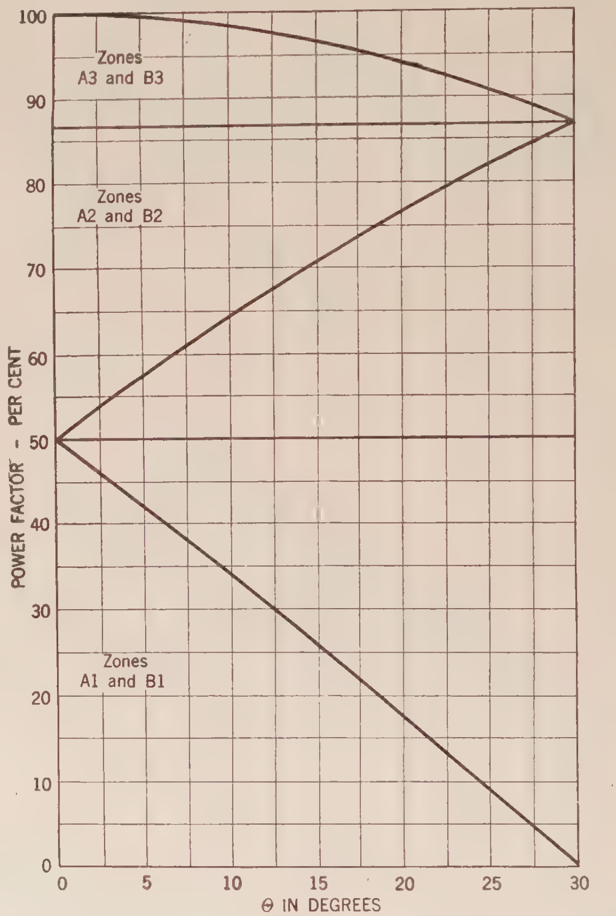


FIG. 3

separately and find a ratio of 0.73. This at once shows that we had either $(30 + \theta)$ and $(90 - \theta)$ at about 35 deg. or $(90 - \theta)$ and $(30 - \theta)$ at about 45 deg. Using the ratio of either element before interchanging to the disk velocity after interchanging will distinguish between these two; it is entirely superfluous to use both. Thus if we take the ratio of the fast element before interchanging to the disk velocity after interchanging and found it 0.56 we would know that originally we had $(30 + \theta)$ and $(90 - \theta)$ while if this ratio had been 3.84 we would have had $(90 - \theta)$ and $(30 - \theta)$ originally.

Thus to make out check we need two ratios: 1st. that between the two elements originally, and for convenience let us always take the ratio of the slow element to

the fast so that our ratio will always be less than one (call this ratio $A$), and 2nd. that of one element before interchanging to either element after interchanging and here let us agree to always take that of the fast element before interchanging to either one after interchanging (call this ratio $B$). Due to the similarity before discoverd any combination of ratios $A$ and $B$ will apply to each of the six zones which are each 30 deg. wide. There will be just three groups of ratios $A$ and $B$: where $A$ is $(30 + \theta)$ to $(30 - \theta), -(30 + \theta)$ to $(90 - \theta)$, and $(30 - \theta)$ to $(90 - \theta)$.

Bearing these facts in mind we may draw up Tables III and IV. In Table III are given the three groups of ratios $A$ and $B$ computed for every 3 deg. from 0 to 30 deg.—the value of $\theta$ being shown on the right hand side. In Table IV are given for each group of ratio combinations the connection group which is possible for each zone. The zones are listed at the right. In order to determine definitely the power factor which the ratios $A$ and $B$ admit Fig. 3 may be used. From Table III we get the degree (from 0 to 30) corresponding to the ratio combination we have found and from Table IV we get the connection group and zones possible. Taking this information to Fig. 3 where degrees from 0 to 30 are abscissas we may determine the actual power factor for each zone.

An example may make the general scheme clearer. The one given is actual test data taken from a meter on the feed to a lighting bus. The readings were taken during the day when there was little load and the disk velocities were therefore low. The meter was a Westinghouse Type $A$ 0 switchboard type—5-amperes 100-volt—used with instrument transformers. The two elements are designated top and bottom as the terminals are brought out at the top and bottom of the back of the instrument.

ORIGINAL CONNECTIONS

Top Element, 1 rev. in 38 sec. Velocity—1.58 rev. per min.

Bot. element, 1 rev. in 34 sec. Velocity 1.76 rev. per min.

Ratio $A$—0.90

AFTER INTERCHANGING

Top element, 1 rev. in 122 sec. Velocity—0.492 rev. per min.

Bot. element, 1 rev. in 43 sec. Velocity—1.40 rev. per min.

Here it is evident that the two elements do not run at the same speed after interchanging but that they do (approximately) before interchanging. This shows at once that, regardless of other possible errors, the potential leads were interchanged originally giving one of the groups 4, 5 or 6. To deal with this situation, therefore, we merely consider the readings marked "AFTER INTERCHANGING" above as the original connection and vice versa. In this way we get: Ratio $A = 0.35$ and Ratio $B = 0.84$. To get ratio $B$ the average of the two velocities after interchanging is used: 1.58 and 1.76 respectively

Turning now to Table III we see that the only ratio combination which contains such a pair of ratios is combination three at about 14 degrees. Table IV now gives the possible connections. This meter being on a lighting bus with no synchronous apparatus connected, we know the power factor is lagging and therefore may ignore the $B$ zone possibilities. Using Table IV and Fig. 3 we see that we have the following possibilities:
Group 1—power factor 27.5 per cent.
Group 3—power factor 68.5 per cent.
Group 3—power factor 97.0 per cent.
As in this case we know enough of conditions to know that as the load is mostly transformer magnetizing current the power factor must be low and thus the third possibility of Group 3 at power factor 97.0 per cent may safely be thrown out.

TABLE III.

| Comb. I | | Comb. II | | Comb. III | | |
|---|---|---|---|---|---|---|
| A | B | A | B | A | B | $\theta$ |
| 000 | 1.00 | 1.00 | $\alpha$ | 000 | 1.00 | 0 |
| .058 | 1.06 | .942 | 17.0 | .062 | .942 | 3 |
| .114 | 1.13 | .885 | 8.77 | .129 | .885 | 6 |
| .167 | 1.20 | .832 | 5.99 | .202 | .832 | 9 |
| .219 | 1.28 | .781 | 4.57 | .280 | .781 | 12 |
| .268 | 1.37 | .732 | 3.73 | .366 | .732 | 15 |
| .326 | 1.46 | .684 | 3.07 | .462 | .684 | 18 |
| .362 | 1.57 | .636 | 2.76 | .570 | .636 | 21 |
| .410 | 1.69 | .592 | 2.44 | .692 | .592 | 24 |
| .454 | 1.84 | .545 | 2.20 | .833 | .545 | 27 |
| .500 | 2.00 | .500 | 2.00 | 1.00 | .500 | 30 |

TABLE IV.

| Comb. I | Comb. II | Comb. III | Zone |
|---|---|---|---|
| Gr. III | Gr. II | Gr. I | A 1 |
| Gr. I | Gr. II | Gr. III | A 2 |
| Gr. II | Gr. I | Gr. III | A 3 |
| Gr. III | Gr. I | Gr. I | B 3 |
| Gr. I | Gr. III | Gr. II | B 2 |
| Gr. II | Gr. III | Gr. II | B 1 |

There is a very simple way to determine between the other two. Turning back to Fig. 2 we see that Zones $A$ 1 $A$ 3, and $B$ 2 are the same as $A$ 2, $B$ 1 and $B$ 3 but upside down. That is the curves that in zones $A$ 1, $A$ 3 and $B$ 2 increase in value with a decrease in power factor do exactly the opposite in zones $A$ 2, $B$ 1 and $B$ 3. This at once suggests that if we had some simple means of changing the power factor we could determine between these two types of zones by watching the behavior of the meter. A practical lowering of the power factor may be obtained by inserting a resistance in the potential circuit. The potential circuit of a watthour meter is practically all inductance and therefore the current flowing in this circuit lags behind the voltage phase by practically 90 deg. The insertion of resistance, therefore, has the effect of advancing the phase of the current in the potential coil. Advancing the phase of the current in the potential coil is equivalent to retarding the phase of the current in the current coil, which, of course, corresponds to a lowering of the power factor.

The most convenient resistance to use is a 25-watt lamp. Using this the following readings were obtained:

TOP ELEMENT

Before using res. 1 rev. in 122 sec. Disk vel. 0.492 rev. min.

After using res. 1 rev. in 41 sec. Disk vel. 1.46 rev. min.

BOTTOM ELEMENT

Before using res. 1 rev. in 43 sec. Disk vel. 1.40 rev. min.

After using res. 1 rev. in 86 sec. Disk vel. 0.695 rev. min.

Thus we see that the insertion of the resistance has the effect of increasing the velocity of the slow element and decreasing the velocity of the fast element. A glance at Fig. 2 will show that this is what would happen in zone $A$ 1 if the power factor were lowered but is the opposite of what would happen in zone $A$ 2. This cuts out the 2nd possibility and leaves us only Group 1 power factor 27.5 as our actual meter connection. Thus we conclude that the meter was incorrectly connected at first — the error being that the potential leads were interchanged.

There is one phase of the subject which has been given considerable attention in previous treatments but which we have not yet mentioned. This is the direction of rotation. Above 50 per cent power factor, in a correctly connected meter both elements should rotate in the same direction, and below 50 per cent the slow element should rotate in a direction opposite to that of the fast element. This reversal at 50 per cent power factor is due to the cosine expression of $(30 + \theta)$ where for $\theta = 60$ deg. (which is 50 per cent power factor) the angle $(30 + \theta)$ passes from the first to the second quadrant and the cosine changes from + to −. This question of direction of rotation and the further fact that on interchange of potential leads one of the elements reverses under certain conditions seems significant and on the surface would indicate the possibility of a criterion for checking. Investigation proves, however, that this is not the case.

Adverting again to Fig. 2 we observe that this reversal of one element as the power factor passes certain points is also subject to the same recurring symmetry that affects the other factors. In zones $A$ 1 and $A$ 2 it is the expression cos $(30 + \theta)$ which reverses at $\theta = 60$ deg.: in zones $A$ 3 and $B$ 3 it is cos $(90 - \theta)$ when $\theta = 0$ deg.: and in zones $B$ 2 and $B$ 1 it is cos $(30 - \theta)$ when $\theta = -60$ deg. To go into this side of the problem in detail would take up more time than the results obtained would warrant. It is sufficient to state that no additional light can be thrown on the subject by noting direction of rotation. Therefore in making a check we may ignore entirely the direction of rotation as we did in the example given. After having obtained our final results we shall know by the power factor determined whether or not one element should rotate in the negative direction. In the example given the slow element should be rotating in the reverse direction and if it is not doing so, either the potential or current coil of that element will have to be reversed before the meter can be pronounced correctly connected.

It may be worth while here to show why Prof. Kouwenhoven's test before mentioned is not reliable. It is true that if the meter is properly connected and the potential leads interchanged the meter will stop. As we have seen, both elements read the same on interchanging the potential leads and thus the only requisite for stopping is that one element should reverse on interchanging. It happens that all three groups with power factor above 50 per cent and both elements rotating positively originally will stop on interchange. Take Group 2 for example. This is

$$+ E_{32} I_2 \cos (30 - \theta)$$
$$+ E_{12} I_3 \cos (90 - \theta)$$

On interchange this becomes

$$+ E_{12} I_2 \cos (30 + \theta)$$
$$- E_{32} I_3 \cos (30 + \theta)$$

By reference to Fig. 2 it will be seen that $E_{32} I_3$ will be negative while $E_{12} I_2$ is positive as indicated by the signs placed before the expressions above so that the meter will stop.

While on the subject of reversal it might be well to take up the exception referred to previously. The statement was made that no attention need be paid as to how the leads were connected either at the meter or at the transformers with one exception. This exception is when three leads only are brought out from the instrument transformers and a reversal of one set of transformer leads is made and then the wrong common wire selected at the meter. In such a case we get a voltage (or current as the case may be) at the meter which is $\sqrt{3}$ times the true value. This situation may be readily discovered in the potential circuit by using a lamp as a voltage indicator. On the current circuits the simplest test is to short circuit the current coil of each element successively. If the entire meter stops when either element is short-circuited it is an indication that the wrong common wire has been taken.

It might be well to add here to fill in the subject that other manipulations than the interchange of potential leads are possible such, particularly where three leads only are brought to the meter, as disconnecting the common lead but leaving the two elements tied together at that point. In all checks however we have to face the inherent symmetry of the system and without knowledge of the power factor no solution is possible. With a knowledge of the power factor the method of checking given is as simple as any.

Summarizing our conclusions we may determine by the method described three possible groups of connections existing in 6 zones from a power factor of 0 per cent lagging to 0 per cent leading, and may determine the actual power factor possible within each zone. By inserting resistance in the potential circuit we may cut these six zones down to three no two of which are adjacent. As it is indeed rare when one does not know the power factor of a circuit to within 60 deg. we can ordinarily determine the actual connection group and power factor of our original connection. With total ignorance of power factor, however, we cannot get nearer than three possibilities at different power factors.

# Discussion at Pacific Coast Convention

## HIGH-VOLTAGE SWITCHES, BUSHINGS, LIGHTNING ARRESTERS—EXPERIENCES OF THE SOUTHERN CALIFORNIA EDISON COMPANY ON ITS 60,000, 150,000 AND 220,000-VOLT SYSTEM[1] (MICHENER), HIGH-VOLTAGE CIRCUIT BREAKERS[2] (COFLEY), MAGNETO-MECHANICAL LOADS ON BUS SUPPORTS[3] (ROBINSON),

DEL MONTE, CAL., OCTOBER 3, 1923

**J. S. Thompson:** I would like to have you consider what we believe is a step in the right direction in regard to oil circuit breakers. Our factory has developed an oil circuit breaker with six breaks per pole, which is not a new idea at all. We have done it in a novel way in that we have not increased the number of pieces of insulation between the conductors and the ground, but have simply introduced an auxiliary insulation between breaks. This auxiliary insulation is far from sufficient to maintain itself against the line's voltage, but it is only subjected to an impressed voltage at the instant during which the breaker is between the closed and the open position; it is of bakelite and relatively small and failure of this auxiliary insulation simply would cut out certain of the breaks in the circuit. We have such an installation on a 60,000-volt line. This breaker after breaking thirteen short circuits produced by the test of various fuses which failed to open the circuit, was then tested on direct dead short circuit. After having been tested once with no evidence of any form of distress, the engineers took the bold step of putting this breaker on the loaded system of the Pacific Gas & Electric Company, which was at that time being contributed to by Pit River, Drum Electra, Oakland and San Francisco. The breaker was subjected to short-circuit operations with this power concentrated on it (though I will have to say that the power was brought to this distributing point by a 110-kv. system and transformed to 66-kv.), so you will see that the breaker was put to a thorough test. It operated at 2000 amperes, which immediately dropped to 1350 or 1400. A Westinghouse relay closed the circuit in about five cycles and then there were consumed ten cycles for the mechanical operation of the tripping coil, and the movement of the blade out of contact, and nine cycles of diminishing amperes while the arc was being drawn—then five cycles between the rupturing of the arc and the end of the travel of the oil circuit breaker.

So it took a total of just thirty cycles for the switch to range from the impression of the short through to the actual coming to rest of the switch. That was repeated again after the circuit breaker was opened and very minor injuries were shown, simply a certain amount of pitting of the arcing tips such as might be expected. The circuit breaker is in shape to be closed in again on a similar load.

**R. W. Sorensen:** Until very recently oil switches have found very little place in my technical experience, but within the past few weeks a problem involving the use of oil switches made it desirable to search our technical literature for articles expounding the theory of oil circuit breakers.

I found articles discussing mechanical features, test data, and applications, but almost nothing seems to have been printed in American technical literature as to the theory of oil circuit-breaker design.

Eventually I discovered in a recent number of the "Revue Generale de L'electricite" an article on "Oil Switch Design" by Mr. P. Charpentier who signed himself Chief Designer of Service Apparatus in a factory at Jeumont, France, and a series of papers by D. R. Davies published in the London Electrician, the first of which appeared in a number published June 16th, 1922.

1. A. I. E. E. JOURNAL, Vol. XLII, 1923, December, p. 1251.
2. A. I. E. E. JOURNAL, Vol. XLIII, 1924, January, p. 17.
3. A. I. E. E. JOURNAL, Vol. XLII, October, p. 1063.

These papers present the subject of oil circuit breakers entirely from a theoretical point of view but the language of the authors indicates men familiar with the manufacture and use of oil circuit breakers.

Mr. Davies' paper includes this definition 'Breaking capacity may be defined as the maximum kilovolt amperes which the circuit breaker can break under prescribed conditions, at stated intervals, a specified number of times.''

I have found it interesting to attempt to apply the theories advanced in these papers to some oil switches now made by one of our well known oil switch manufacturers, and these results I should like to call to your attention, not because of any conviction as to their accuracy in determining from the dimensions, and speed of operation of a switch just what rating it should have, but rather to stimulate a research program which will develop our knowledge of the theory of switching, and thereby give us a more definitely rated product.

Mr. Davies' first article which has to do largely with the carrying capacity of switch parts as determined by their thermal properties, and eddy current set up in them, needs no discussion at this time.

The facts pointed out in his second paper are the size of arc as determined by the current to be interrupted and its persistance as determined by voltage, switch speed, and stored energy in the circuit.

Also there are many other important phenomena discussed in this paper but we have time to glean only some apparent evidence as to the futility of long breaks, the uncertainty of reliance upon explosion chambers, and an important reference to Dr. Bauer's report to the Swiss Commission. From Dr. Bauer's report we have two important constants, one the energy factor of 0.07 as a maximum for the relation between kv-a. interrupted and the amount of energy which must be dissipated in the arc; the other is the figure 46.5 which represents the number of cubic centimeters of gas liberated for each kw. second of energy which must be taken up by the oil. These data were selected not because they are of necessarily greater importance than the other data given, but rather because they are likewise included in the formula by Mr. Charpentier, the application of which I wish to call your attention.

Time of break is fundamental, and according to Charpentier is equal to $w/v$ where $U$ is voltage per break and $V$ is average velocity of blade in cm. per sec. This constant was used in the Charpentier formula for standard switches with two breaks in series, but if applicable directly to two breaks, should certainly also indicate much advantage for several breaks in series, even though some constant must be applied to allow for a possible uneven distribution of the voltage over the several breaks.

For example, last week I applied the Charpentier formula to several 45-kv. switches of standard make with the following results. Two break switch theoretical rating 3850 amperes. This switch is known to have interrupted successfully a number of times a short of 1,000 amperes, but finally it failed to properly care for a short of about this value. This shows a use of the formula not intended or else an omission of some factor that should be included. A four break switch of the same design shows by calculation a rupturing capacity of about 11,000 amperes instead of the 3600 which experience shows to be its probable rating. Using eight breaks the calculated rupturing capacity is 30,000 amperes.

We have however, a better check on a 30,000 ampere switch, from a known record of the operation of a 45-kv. switch with two breaks used on a 16.5-kv. circuit. The calculated breaking capacities for this switch 10,000 amperes, 27,600 amperes, and 103,000 amperes, for two, four, and eight breaks respectively. The four break switch actually did successfully rupture 20,000 amperes without damage.

Two sets of observations I have made also seem to check the value of the multi-break switch. One is the addition of more series breaks, without any other changes has transformed faulty operating switches into perfectly satisfactory ones.

The second is that when two switches of like design but with different number of breaks are in series on a short circuit, the switch with the greater number of breaks shows less carbon deposit from the oil and less burning of the switch clip, than does the one with the smaller number of breaks.

**J. P. Jollyman:** What kind of oil was used in the test?

**J. S. Thompson:** We used a mineral sea oil, that is, one that is as free from water and acid as possible. We purposely avoid attempting to furnish a high grade oil. So, we use a mineral seal oil.

**H. Michener:** I would like to ask what the test value of that oil was when the experiment started?

**J. S. Thompson:** I don't think I am able to answer that because I don't think we tested that particular supply of oil. This oil, you know, deteriorates in a breaker.

**A. J. Bowie:** I would like to ask if there was any explosion chambers on this 220,000-volt breaker; also how many breaks they had and what was the most severe test to which the breakers had been subjected?

**R. M. Spurck:** In Mr. Copley's paper reference is made to the practise of lowering the transmission voltage by field control in order to extinguish short circuits or flashovers. Such procedure, although effective, will, or has the disadvantage that it generally interrupts service and is liable to cause falling out of synchronous or induction apparatus in the area of the lowered voltage. The newer practise, namely, that of using automatic oil circuit breakers in combination with suitable relay schemes, makes it possible in net works or parallel lines, to automatically drop a defective section of the line without interrupting the service.

Oil circuit breakers are available for interrupting any voltages and currents that are commercially required. These high-voltage breakers are necessarily expensive. This expense is due, primarily, to the large clearance required for insulation. That is, a breaker designed to give the insulation for a 220,000-volt system, will in general, have an interrupting capacity comparable with normal requirements of such a system. In spite of the expense of these breakers, it is believed that their use is justified for sectionalizing purposes because the fixed charges and operating expense on them is small compared with the benefits derived from continuity of service.

One of the types of breakers in operation on the 220,000-volt system on the Pacific Coast utilizes the explosion chamber principle. The advantages of the explosion chamber principle are many and among them are the following: In the inherent speed characteristic, that is, the pressure in the chamber acting on the moving contacts as a piston accelerates the opening speed by the amount it can load. The effect of the increased speed of the opening is also obtained by the pressure inside the chamber causing a rapid movement of oil through the breaking contacts. It is possible, by changing the clearance between the opening in the explosion chamber and the moving contacts to regulate the rate of liberation of gas from the explosion chamber to the outer tank and thereby control the pressure in the outer tank. The ability to control this pressure permits the maximum interruption to be obtained from a given structure. The expulsion of gas into a body of cooled oil cools the gas, reducing its value and causing the breaking capacity to be increased.

The interrupting rating of a flow exchange type breaker has been determined by tests not only in the field, but also in the factory. The factory tests have been made under the worst conditions, namely, that of opening the circuit of a fully excited generator directly at the generator. The factory equipment consists of a 27,600-kv-a. generator complete with high-voltage transformers, reactors, oscillographs, and speed and pressure measuring devices. Such apparatus, for instance, enables us to determine the magnitude of the pressure in the tanks, or explosion chamber, the rate of pressure formation, the arc length and other factors affecting the rupturing capacity. From this definite data and conversion factors obtained therefrom, calculations can be made for other breakers.

In connection with what Mr. Sorensen said, I might add that all of the theories so far published that I have seen have constants in them that have not been adequately determined. For instance, taking a 15,000-volt breaker, opening a low current, the arc duration will be from five to six half cycles. However, if the same breaker is called upon to interrupt 35,000, 40,000 or 45,000 amperes, the arc duration drops down to one-half cycle.

**A. J. Bowie:** I would like to ask Mr. Michener what the short circuit would be on a 220-kv. line?

**H. Michener:** I don't know.

**E. R. Stauffacher:** I would like to emphasize something that Mr. Michener said in regard to the operation of the 220 oil circuit breaker. That is we do not know what amount of current the breaker had to interrupt. It might be stated that the current balanced relays were set to operate when an unbalance of 360 amperes occurs. The probable current interrupted was in the nature of 800 or 900 amperes.

I would like to emphasize as strongly as possible that there is a great need for a discharge recorder on lightning arresters. That is, a discharge recorder which will give a reliable record of the time, and if possible, the magnitude of each discharge, and which will be sufficiently rugged and inexpensive so that it can be installed on a large number of arresters. Such a record taken over a few years, would go a long ways toward settling the controversy as to whether lightning arresters justify their expense.

Time and again, we in the Southern California Edison Company, have wished we had some sort of a recorder available for the studying of the arresters. We have developed a discharge recorder which will give the time, but which does not give the quantity of current which was discharged. In fact, the instruments used in the past have been sometimes destroyed, at other times the chart has been destroyed.

If the manufacturers could see fit to attack this problem and develop some kind of an inexpensive recorder, I believe it would put the question of the application of lightning arresters on a much more definite and reliable basis.

**O. R. Schurig:** In the paper are given formulas expressing the electromagnetic force due to short-circuit currents in parallel conductors. It appears from the paper that the formulas are intended to be used for the calculation of the loads acting on the busbar supports, during short circuits, for the purpose of obtaining the strength required for the supports. In other words, formulas defining the electromagnetic force for a given value of current appear to be represented in the paper as defining, at the same time, the load acting on the support. While it may seem from mere superficial analysis that, in a busbar structure having a number of equal spans as a continuous beam, each support would be acted on by a load equal to the electromagnetic force per span,—a more thorough examination will show that the maximum load acting on the bus support will often differ materially from the maximum electromagnetic force per span. The reasons are (1) that the electromagnetic force is suddenly applied having periodic variations, and (2) that the busbar span and the supports have each their own natural frequencies and consequently respond differently to applied electromagnetic forces of different frequencies. Consequently, the formulas in the paper, give, in general, only roughly approximate values of actual loads acting on the bus supports during short circuits. Experiments, the results of which will be published later, have shown that the maximum load which the support has to withstand is in many cases, much smaller than the electromagnetic force (per span) calculated for the peak value of short-circuit current, but may rise well above the electromagnetic force so

calculated when the busbar is in resonance with the electromagnetic force. Both resonant and non-resonant structures occur among the customary designs.

The difference between the electromagnetic force and the load acting on the support will be seen more clearly from the following considerations:

When an a-c. short-circuit current is suddenly caused to flow in a pair of parallel busbars, the two bars carrying equal and opposite currents, a rapidly varying pulsating force tending to push the bars apart is suddenly applied to the two conductors. The force is called the electromagnetic force. It is the driving force which tends to set the busbars into motion. The deflection of the busbar, and hence the stress set up in the busbar material as well as the load on the support, depend not only on the magnitude of the driving electromagnetic force, but also to a large extent on the ability of the busbar to respond as a vibrating body to the rapidly recurring force pulses. The stresses caused in the busbar cross-section during its vibratory motion increase with increasing deflection of the busbar span and reach a maximum at the instant of its maximum deflection. In stress determinations it is convenient to consider the equivalent uniformly distributed dead load per span of busbar, to be called briefly the "equivalent busbar load," which may be defined briefly as the uniformly distributed dead load (per span) which creates the same busbar deflection (relative to supports) as that produced by the driving electromagnetic force in the busbar span at any instant during the vibratory motion. Thus the character of the equivalent busbar load is indicated by the character of the busbar deflection.

In order to form a picture of the busbar deflections, it is necessary to consider the various components of the electro-magnetic force causing the deflections. It can easily be shown that a displaced sine-wave short-circuit current produces, at the beginning of the short circuit, an electromagnetic force of the following three components: a direct component, an alternating component at current frequency, and an alternating component at twice current frequency. It follows than that a busbar of very low frequency with respect to the current frequency, will respond mainly to the direct force component, but only very feebly to the alternating force components, and will, therefore, vibrate almost purely at its own natural frequency, approximately as if the alternating electromagnetic force components were entirely absent. Thus the maximum busbar deflection, and hence the maximum busbar load, may not occur until several (current) cycles after the peak current has occurred. Hence the maximum load is but remotely dependent on the initial peak electromagnetic force.

On the other hand, a busbar of high frequency, with respect to the current frequency, will respond to all the electromagnetic force components with practically equal fidelity, in much the same manner as a high-frequency oscillograph vibrator traces true images of composite low-frequency current waves. Now, the maximum busbar load will be practically equal to the maximum electromagnetic force per busbar span.

Should, however, the busbar be at resonance with the electromagnetic force, *i. e.*, having a natural frequency equal to the frequency of one of the alternating components of the electromagnetic force, the busbar will show a decided preference for the vibrations at the resonant frequency. Cumulative vibrations will occur, limited in magnitude only by the relatively low motional resistance of the busbar span. Thus the maximum equivalent busbar load may occur considerably later than the maximum short-circuit current, but may reach a value materially greater than the peak electromagnetic force.

The above considerations indicate that the maximum busbar load will frequently differ substantially from the peak electromagnetic force, both in regard to magnitude and time of occurrence. The maximum support load will not generally be exactly equal to the maximum busbar load, because the support also has a natural frequency of its own, largely independent of the busbar natural frequency, and will therefore respond selectively to the various frequencies of the driving-force components. Consequently, the support load will differ, in a great many cases, from the maximum electromagnetic force.

To summarize: The formulas in the paper give definite values of electromagnetic force. The maximum load acting on the supports during short circuits very often differs materially from the maximum electromagnetic force, the relationship depending on the natural frequencies of the busbar and of the supports as well as on the short-circuit current, as will be more fully brought out in a subsequent paper. Formulas for electromagnetic force, such as those presented in the paper, give as a rule only a very rough approximation to the support loads due to short-circuit currents.

**E. G. Allen:** Mr. Robinson calculates the force between conductors under a three-phase short-circuit which occurs at the instant of zero voltage in phase $a$. Under these conditions he finds the force at the moment the current in conductor $a$ is a maximum which he calls $1.8\sqrt{2}\,I_3$, evidently allowing 10 per cent decrement in the first quarter cycle. At this instant the current in $b$ and $c$ would be $-0.9\sqrt{2}\,I_3$, as the current in $b$ equals that in $c$ and the sum of currents in $a$, b, and $c$ equals zero. Under these conditions, the instantaneous force between conductors is—

$$S_{AB} = \frac{5.40 \times 1.8\sqrt{2\,I_3} \times 0.9\sqrt{2\,I_3}}{10^7\,D} = -\frac{17.5\,I_3^2}{10^7\,D} \qquad .A$$

$$S_{BC} = \frac{5.40 \times .9\sqrt{2\,I_3} \times 0.9\sqrt{2\,I_3}}{10^7\,D} = +\frac{8.75\,I_3^2}{10^7\,D} \qquad .B$$

$$S_{CA} = \frac{5.40 \times 0.9\sqrt{2\,I_3} \times 1.8\sqrt{2\,I_3}}{2 \times 10^7\,D} = -\frac{8.75\,I_3^2}{10^7\,D} \qquad .C$$

$$S_A = -\frac{26.25\ I_3^2}{10^7\,D}$$

$$S_B = +\frac{26.25\ I_3^2}{10^7\,D}$$

$$S_C = 0$$

Although the above equations show the force at time of maximum current in $a$, they do not give the condition of maximum stress. Under the short circuit conditions assumed, the force in the middle conductor is a maximum 160 deg. after the moment of short circuit, when it is, without decrement $\dfrac{35.7\,I_3^2}{10^7\,D}$. The maximum force in the outer conductor is slightly less and occurs $164°\,28'.65$ after the moment of short circuit. However, analysis shows that the stress in conductor $a$ is still greater when the short circuit occurs 15 deg. before the current in $a$ is a maximum, and that the maximum force occurs 180 deg. after the short circuit. Under these conditions the instantaneous force on $a$, without decrement, is equal to $\dfrac{34.8\,I_3^2}{10^7\,D}$ and on $b$, $\dfrac{37.4\,I_3^2}{10^7\,D}$.

If 10 per cent current decrement is allowed, these values will be reduced to 81 per cent of their given value, but it should be borne in mind that these are instantaneous values of the force upon the conductors. The average values over the cycle are much less. The difference is a pulsating force tending to put the bus bars into vibration. The inertia of the bar is generally such that if the average force were withstood, the pulsating force would cause vibrations amounting to but a small fraction of an inch. This leads to the thought that stresses set up by short circuits might be greatly reduced if some sort of flexible support were provided which would permit the pulsating forces to be absorbed by the inertia of the bar.

The analysis leading to the above is briefly as follows:

Neglecting decrement of current, the equations of the unsymmetrical short-circuit currents are:

$$i_1 = A\,[\cos(\theta + \alpha) - \cos\alpha\,]$$
$$i_2 = A\,[\cos(\theta + \alpha - 120) - \cos(\alpha - 120)\,]$$
$$i_3 = A\,[\cos(\theta + \alpha - 240) - \cos(\alpha - 240)\,]$$

Where $A$ = max. value of symmetrical current

= elapsed time (degrees) between moment of short circuit and moment under consideration.

= time (degrees) between moment of max. current and moment of short circuit.

$$\text{Force in middle bus} = \frac{5.40}{10^7\,S}\,(i_2\,i_3 - i_1\,i_2)$$

$$\text{Force in outer bus} = \frac{5.40}{10^7\,S}\left(i_1\,i_2 + \frac{i_1\,i_3}{2}\right)$$

Where $S$ = distance between bus bars in a plane—

From the above:

$$i_2\,i_3 - i_1\,i_2 = \sqrt{3/2}\,A^2\,[\sin(2\theta + 2\alpha - 240) - 2\sin(\theta + 2\alpha - 240) + \sin(2\alpha - 240)\,]$$

This is a maximum or minimum with respect to $\alpha$ when

$$\alpha = -15 - \theta/2 \text{ or } 75 - \theta/2 \text{ or } 165 - \theta/2$$

It is maximum or minimum with respect to $\theta$ when

$$\theta = 40 - 4\,\alpha/3 \text{ or } 160 - 4\,\alpha/3 \text{ or } 280 - 4\,\alpha/3$$

For maximum with respect to both $\alpha$ and $\theta$

$$\theta = 180 \text{ deg.}$$
$$\alpha = -15 \text{ deg. or } 75 \text{ deg. or } 165 \text{ deg. or } 255 \text{ deg.}$$

Under any of these conditions

$$i_2\,i_3 - i_1\,i_2 = 2\sqrt{3}\,A^2 \text{ and } F = \frac{18.72\,A^2}{10^7\,S}.$$

If $I_3$ = root mean square current $= A/\sqrt{2}$

$$F = \frac{37.4\,I_3^2}{10^7\,S}$$

**L. H. Robinson:** I agree with Mr. Schurig that the method submitted in my paper, gives only approximate results and consequently I prefer to use a liberal factor of safety. If vibrations of the bus and its supports, due to currents of ordinary frequency (25, 50 and 60 cycles per second) with common sizes of bus bars, lengths of span, etc., may augment or partially neutralize the external force; formulas correlating these factors with the bus currents, and experimental confirmation of these formulas will be valuable and useful.

**H. Michener:** Twelve of the twenty-eight 220-kv. oil switches referred to in the paper have been operating on balanced relays since early in September. These switches have given very satisfactory performance. A ground on a section of line thus protected causes only a momentary drop in system voltage of approximately 10 per cent. After as many as five automatic operations under short circuit to ground conditions and perhaps fifty non-automatic operations for routine line switching, inspections have shown only slight burning on the contacts and some minor mechanical defects.

The longest section of line being switched out automatically up to the present time is 98 miles. About March first, a section of the line 166 miles long will be arranged for automatic isolation on balanced relays.

The actual currant values which occur at the time of a short circuit to ground are very problematic. Using the calculating table which has been constructed for the purpose of studying short-circuit currents on the system, it has been determined that with the present generator capacity the maximum current value on the 220-kv. lines is about 5000 amperes in case of a three-phase short circuit. This is the instantaneous current. In about two-tenths of a second the current is reduced to about half that value.

**A. W. Copley:** With reference to Mr. Bowie's question as to the construction of the 220-kv. circuit breaker which I described, I will say that this breaker is built with two breaks per pole and without explosion chambers.

A high speed of contact separation is obtained by means of arcing contacts held to the stationary contact parts by a spring and latched to the moving contact parts in such a way that the arcing contacts maintain connection until the main moving contacts are open several inches. The latch then releases allowing the arcing contacts to be quickly retrieved upward by means of a spring while the moving contacts are at the same time moving downward at high speed.

Mr. Bowie also asks concerning the tests for the determination of interrupting capacities. Tests at full rupturing capacity on the 220-kv. breakers naturally have not been made because of the inability to obtain the necessary combination of high energy and high voltage for adequately determining such interrupting ability. However, tests have been made on similarly designed breakers for somewhat lower voltages and these have demonstrated their ability to more than meet the guaranteed interrupting capacity. It is fully expected, therefore, that the rated interrupting capacity of the 220-kv. breakers will be found to be conservative when the systems to which they are connected have grown to the point where this rating is reached by the requirements of service.

Mr. Spurck has described another design of circuit breaker for 220-kv. service in which the explosion chamber is utilized. While the value of this device may be open to question in theory, the only complete answer as to the dependability of the breakers will be obtained by service records at a later date. Testing interrupting ability by means if a special generator and other testing equipment is of very great value and should be followed out further. But, it is evident that obtaining of the necessary energy and voltage to make adequate tests on a breaker with an interrupting capacity of more than 1,000,000 kv-a. at 220 kv. is hardly possible at this time.

The theories as to the mathematical determination of oil circuit breaker interrupting capacity as described by Professor Sorensen, are of considerable interest. But the best guide at present in determining capacities is obtained by actual test and operating experience with the various types of breakers. I believe that the factors entering into the determination of rupturing capacity are so numerous and complex that it will be difficult to express the result in a mathematical formula. It is of value, however, to continue to work toward this end along with tests and operating experience from which the final answer must be obtained.

It might be inferred from the discussion by Mr. Thompson that high quality of oil is not of vital necessity in high-voltage circuit breakers. While there is some evidence in favor of such a conclusion, there is also much reliable evidence to the effect that a poor quality of oil has caused many switch failures. It is therefore premature, to say the least, to ignore this factor and until much more is known about breaker operation on high voltages no oil but the best should be used.

## OPERATION OF RADIO IN GREECE TO BE PERMITTED

Some months ago the Revolutionary Government forbade by legal decree the operating of private wireless apparatus in Greece. However, the Ministers of Finance and Marine of the present Government, according to unofficial advices, have now prepared a bill to be submitted to the National Assembly for ratification, by which the operation of private radio sets belonging to Greek individuals will be permitted under certain restrictions and subject to the payment of a license tax.

# The 65,000-Kv-a. Generator of the Niagara Falls Power Company

By W. J. FOSTER AND A. E. GLASS
Fellow, A. I. E. E.
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At the close of the 19th century a notable event occurred at Niagara Falls,—the development of a plant for the utilization electrically of Niagara power. Then, as now, Niagara Falls was recognized as the finest water power in the world, a cataract of great height, fed from the five Great Lakes, constituting a water storage without a rival. It was in keeping with the situation that the first plant was developed with mammoth units, much larger than had been dreamed of up to that time. They were 5000 horse power each, or, translated into electrical terms, 3750 kw., eleven of these units under one roof.

Almost exactly twenty-five years later a generator with nominal rating of 65,000 kv-a. or one capable of 50 per cent greater output than the entire row of units in the original power house, was put into service. This latest generator is the product of the experience gained during the intervening years, It is three-phase, instead of two-phase; it is 12,000 volts, instead of 2200; it is 80 per cent power factor, instead of unity-power factor; it has high internal reactance, instead of low; it has losses at full-rated load equal to approximately 2 per cent of its output, whereas the original had from 7 per cent to 8 per cent; it is of the "conventional," internal-revolving field type, whereas the original had its field revolving outside of the armature; it supports on its stator, by means of thrust bearing mounted at the top, the entire weight of its own rotor and the runner of the turbine, whereas the original had its revolving part supported from an oil-pressure step bearing located underneath; it is located so close to the turbine that it has no lower guide bearing of its own, whereas the original was some 150 ft. above the turbine with several guide bearings intervening; it is equipped with brakes to bring it to rest quickly, whereas the original had no means provided for bringing it to rest, except the shutting off of the water to the turbine; it contains approximately twenty-three pounds of material per kv-a. output, whereas the original contained nearly fifty pounds.

Although the quantity of material in this large generator is less than a half that of the original per kv-a., it is very large as compared with a modern 60-cycle generator of large capacity at the higher speeds that are now common in hydraulic developments. There are three reasons for this generator having such great weight as one and one-half million pounds of material; first, the fact that it is low speed; second, it is low periodicity; third, it was designed for the highest economic efficiency.

Regarding the effect of rotative speed on weight, it may be said, that for the same electrical characteristics the lower the peripheral speed, the greater the weight of magnetic material and copper, and that the lower rotative speed always requires a lower peripheral speed to obtain the proper adjustment between the material that must be used for mechanical structure and that which must be used for the electrical parts. In the case of this generator, the peripheral speed is only 8200 ft. per minute, whereas many 50 and 60-cycle hydraulic generators that have been built at speeds from 200 to 600 rev. per min. have peripheral speeds of 12,000 ft. per min., or higher,—some of them as high as 15,000 ft. per min.

With regard to the effect of periodicity on quantity of material; assuming same output, same characteristics, same rotative speed and same peripheral velocity, the total magnetic flux in the airgap must be the same at all periodicities, but the lower periodicity machine has fewer poles and the flux linked through armature from pole to pole is in inverse ratio to the periodicity, a 25-cycle machine having 2.4 times that of a 60-cycle; hence, a cross section of armature core that many times greater must be provided. Formerly, the lower periodicity permitted of higher magnetic densities in teeth and core of armature, but silicon steels have been developed with such high qualities in the matter of hysteresis losses that the lower periodicity no longer has any advantage in this respect. All periodicities up to 60 cycles are worked at as high saturation as permeability allows. Again, the smaller number of poles in the 25-cycle machine requires a much greater radial depth of pole for heat dissipation reasons, and greatly increased cross section of the copper on the pole. For these reasons, the total quantity of magnetic material in the poles and the total amount of copper in the field-winding are greater than in the corresponding 60-cycle generator.

With reference to increase in material that was introduced in order to obtain the highest economic efficiency, it may be said, that as far as temperatures were concerned, the amount of copper in both armature and field could have been reduced at least 20 per cent, and the amount of magnetic material as much as 10 per cent. In order to obtain extremely high efficiency, it was necessary to reduce several or all of the various kinds of losses, windage, hysteresis and eddy current, $I^2 R$ and load losses. The most important factor in

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the windage losses is peripheral speed; hence, it is generally best to select smaller diameter, although it results in increased magnetic material and copper. Lower hysteresis and eddy losses may be obtained by working at lower densities; consequently, greater amount of material must be used in the magnetic parts. Lower $I^2 R$ losses can be obtained by increasing the quantity of copper. Load losses can be kept lower by conservative design in the matter of armature reaction, but the size of the machine is increased by reason of the lower armature reaction.

The electrical characteristics of this generator are in accord with what is regarded as best for power-producing purposes in large systems. The ampere turns at no load, 12,000 volts, are almost identically the same as required for rated current on short-circuit.

The calculated armature reactance is 26 per cent.

Unusual features in the electrical design are the low point on saturation curve at rated voltage, made necessary by the requirement of operating continuously at 13,200 volts, 68,250 kv-a. 80 per cent power factor, and the very low-current densities at which copper is working, approximately 1300 amperes per square inch in armature and 1100 in field, in order to obtain the very high efficiency.

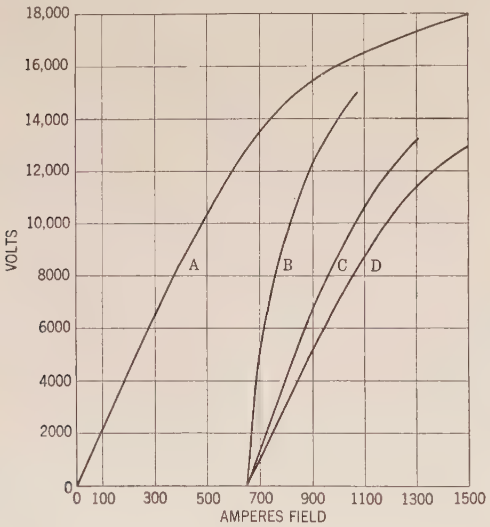


Fig. 1—The 65,000 Kv-a. Generator of the Niagara Falls Power Co.

Saturation Curves
*A*—Open Circuit
*B*—Full Load Current 100 per cent Power Factor
*C*— " " " 80 " " " "
*D*— " " " zero " "

Fig. 1 contains Curves of no load, 100 per cent and 80 per cent power factor full-load saturation.

Fig. 2 shows Curves of Field Characteristics for three conditions, *viz.*, 100 per cent power factor, 65,000 kv-a., 12,000 volts; 80 per cent power factor, 65,000 kv-a., 12,000 volts and 80 per cent power factor, 68,250 kv-a., 13,200 volts.

The fact that this generator is, for the time being, the largest ever built, would in itself be sufficient justification for describing it, but in addition, it contains a few features that are entirely new, as far as the writers of this paper know. Many large vertical hydraulic units have already been built, due to the ever increasing demand for power and to the greater simplicity and economy in power houses and auxiliary apparatus thus obtained. The principal parts of such large generators may be stated as stator frame; stator core; stator winding; shaft; rotor spider; poles; field coils; upper bearings' spider; bearings; oiling system; collector rings. There are numerous detail parts in connection with every one of these major parts that are of extreme importance and worthy of description. Before taking up the major parts in order, we call attention to Fig. 3, which shows the general arrangement of the generator, the stator supported by a continuous base ring, thrust bearing carrying the total weight of the generator and water-wheel rotating elements, including water thrust, mounted on the upper bearing bracket. This bracket also carries the generator guide bearing. The water-wheel guide bearing is located directly above the turbine runner. The proximity of generator rotor to turbine runner eliminates a third, or middle guide bearing, which is often placed immediately underneath the generator.

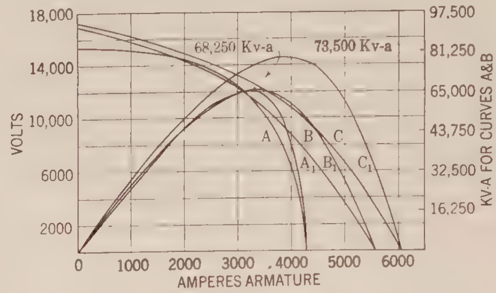


Fig. 2—Field Characteristic Curves
*A*—$A_1$ 100 per cent Power Factor 12,000 Volts 65,000 kv-a.
*B*—$B_1$ 80 " " " " 12,000 " 65,000 kv-a.
*C*—$C_1$ 80 " " " " 13,200 " 68,250 kv-a.

The novel features in this generator are shown in Fig. 3, in the placing of an excitation generator with rating 650-kv-a., the stationary part suspended from the upper bearings' bracket and the revolving part mounted on the arms of the revolving spider of main generator. The collector slip rings for supplying exciting current to this small generator, as also those for main generator, are shown mounted immediately above the thrust bearing. At the extreme top is mounted a speed limiting device. These parts are protected by a housing of pleasing design. This new generator has the same lines as the 32,500 kv-a. generators, installed in the same station about three years ago and designed in accordance with the ideas of the engineers of the Niagara Falls Power Company. Fig. 4 shows the close agreement in outlines of the two generators, the one exactly double the other in capacity, and gives at

the same time a clear idea of the relative space above floor, required by the respective machines.

## Stator

The cast iron stator frame is made in four sections, for purposes of casting, machining, handling in the factory, transporting and erecting at power house. Each section measured 22 ft. across the arc and 10 ft. in height. The sections are keyed, doweled and put together with sufficient bolts to withstand maximum short-circuit strains. Similarly, the complete stator frame is rigidly doweled and bolted to the base ring. The final adjustments for alignment are made by means of adjusting screws in the base ring. At the top of the stator frame is a projecting flange for the attachment of ventilation housing that surrounds the machine, for the purpose of carrying away the warm air.

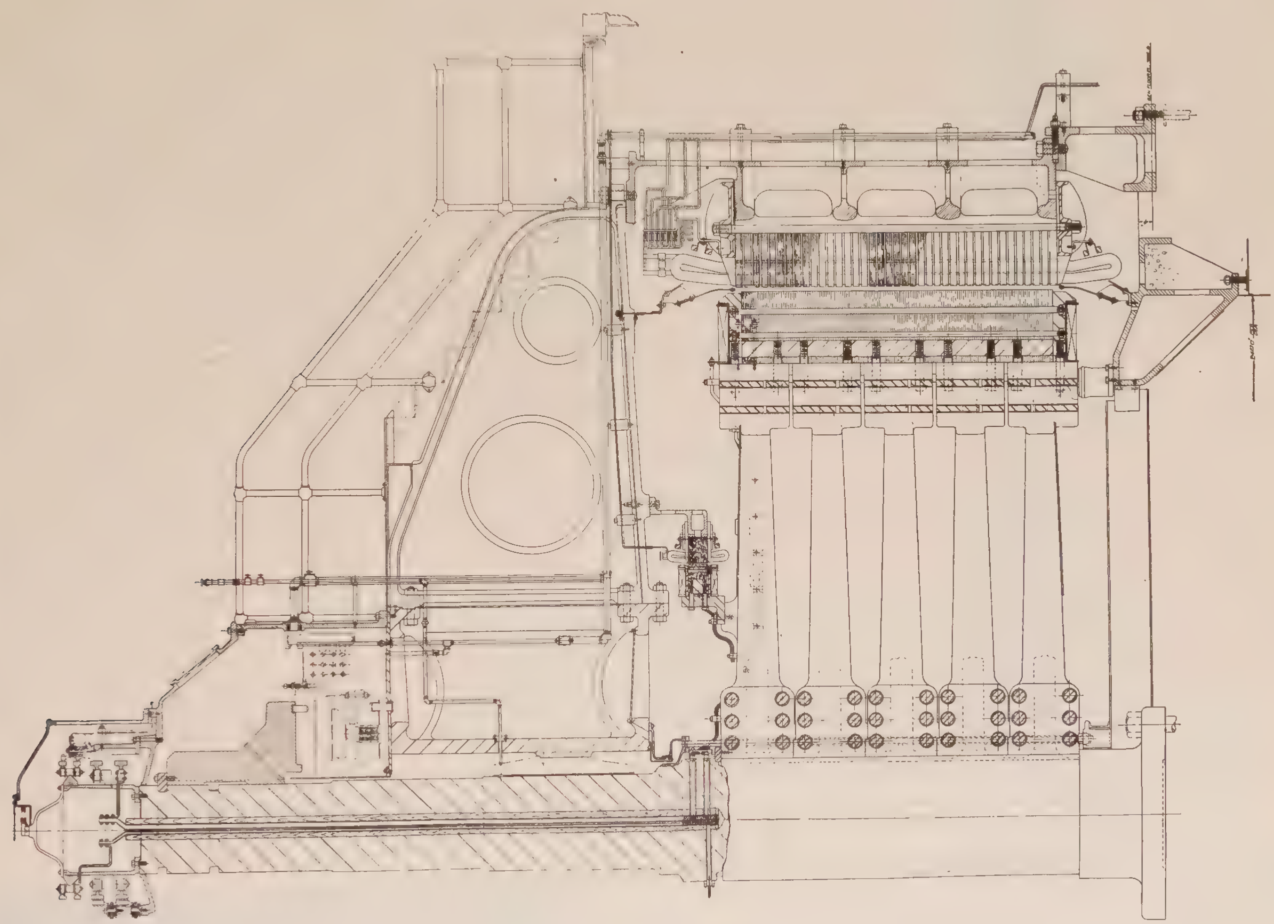

Fig. 3—Cross Section of Assembled Generator

## Stator Core

The laminations of core are assembled on keys attached to stator frame ribs by screws. The core is built up in numerous sections separated from one another by "I" beam space blocks, so as to provide ventilating ducts. The core, by reason of its immense size, is clamped together by extra heavy cast-steel clamping flanges at top and bottom with large bolts running the entire length of the core and located between core and stator frame. By clamping the core with through bolts in this manner, the stator frame is relieved from strains which might exist if the clamping flanges were attached by bolts screwed into the stator frame, as is customary in smaller machines. Shims are provided underneath clamping flanges, in order that any looseness of core may be taken up, in case such looseness should ever develop. The core was assembled at the power house as a complete circle so that the laminations are staggered everywhere and there are no joints in the core, which are sometimes responsible for noise, due to vibrations of the edges of the laminations immediately at the joint.

A special device for assembling and pressing the core was made for this particular installation and is shown in Fig. 5.

The laminations are of the best grade of silicon steel, of same thickness and with every sheet enamelled on both sides, in same manner and with same care as for cores of the largest and most important 60-cycle generators.

## Stator Winding

The armature winding consists of 360 coils, three turns each of rectangular wire, 36 strands in multiple,

spanning 70 per cent of the pole arc. The number of coils per pole is fractional, 12 $^6/_7$, to eliminate higher harmonics. The coils are connected up in four circuits per phase. All connections from coil to coil in the various phase belts, as well as the pole connections and the phase leads at beginning and endings, are made at the top of the machine. Both ends of all phase windings are carried to the busses outside frame for connecting in the differential relay protection apparatus.

The weight of one insulated coil is 186 lb. The weight of the completely insulated and connected winding is approximately 70,000 lb. The windings at heads of machine are laced back to insulated supporting bands with blocking between the coils, while the end connections are arranged in a neat and systematic manner and similarly blocked. See Fig. 6.

The insulation on turns, as also the external insulation, consists of mica, put on in the form of tape with a specially developed varnish as sticker. The coils were subjected to vacuum treatment and moulded to size at different stages of the process. A cross section through the slot, Fig. 7, gives a clear idea of the composition of the conductor and the relative thickness of the insulation.

The insulation of such large coils has been developed with certain desirable characteristics in view, such as the elimination of all pockets for air, or other gases, to avoid internal corona and the introduction of sufficient flexibility to permit bending or yielding when coils are being assembled in deep radial slots or being removed in case repairs are ever made.

A certain amount of heat should be applied before

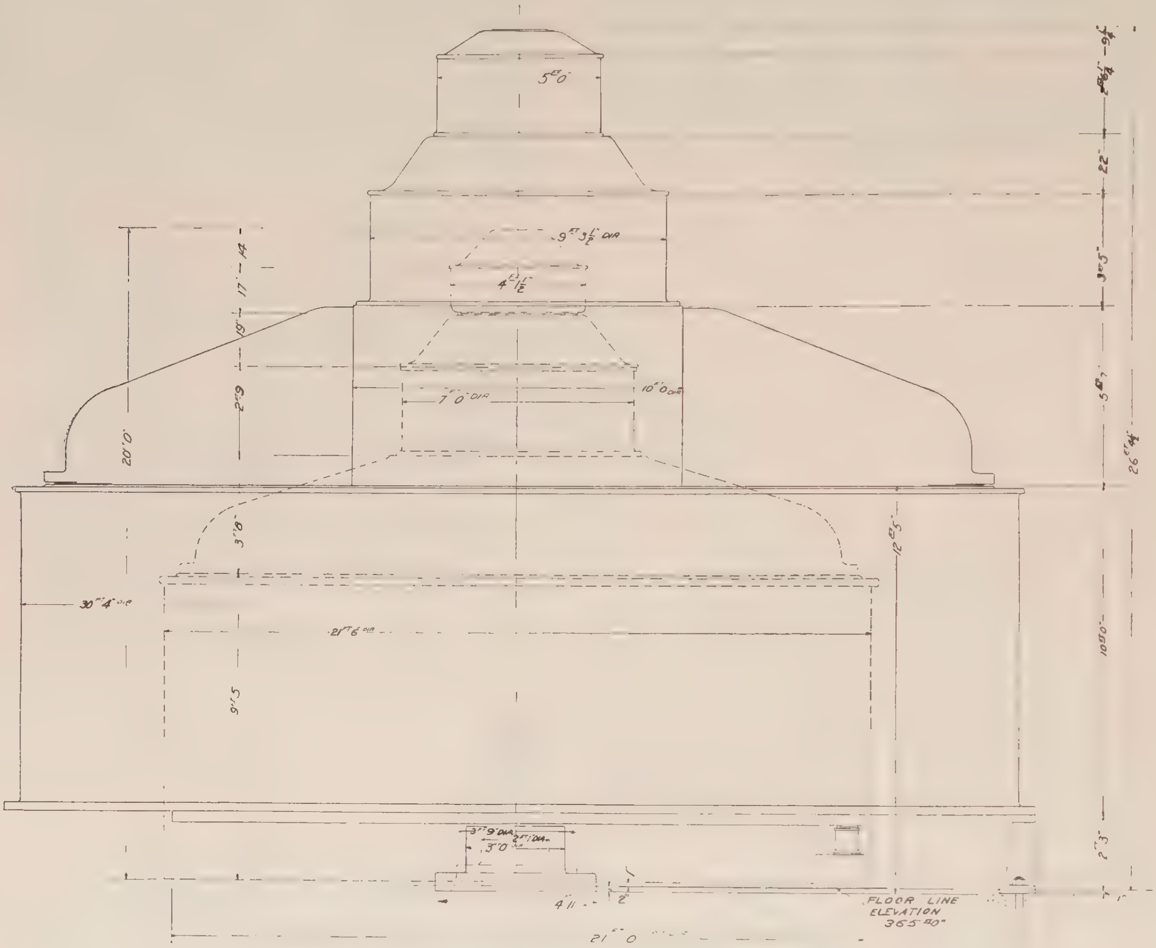

Fig. 4—Superimposed Outlines of 32,500 Kv-a. and 65,000 Kv-a. Generators of Niagara Falls Power Co.

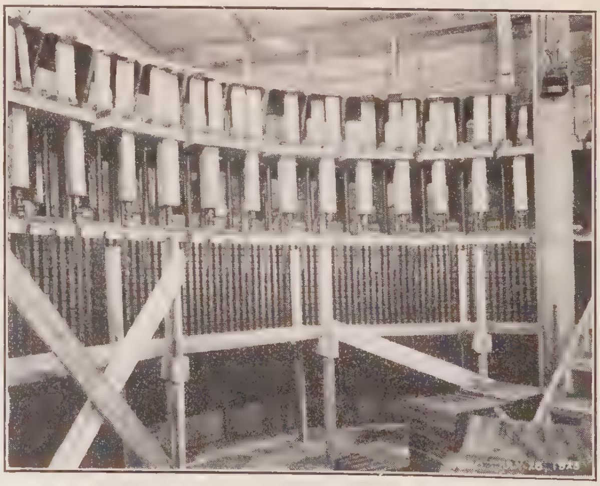

Fig. 5—Stator Core Assembling and Pressing Device

coils are assembled, as also when taking coils out of slots. For the winding of armature of the Niagara generator in the power house a special heating oven was made—Fig. 8.

### Rotor Spider

As a rule, less time is required to design the revolving field of a high-speed large-capacity generator than a low speed generator, for the reason that a laminated or plate center with dovetailed and keyed-on poles is invariably found to be the proper construction for the small-diameter, high-speed rotor. However, for a 107 rev. per min.-generator of large capacity, several alternatives present themselves, requiring much study to decide which is best. Rotor spider may have laminated or plate rim, or it may be made of steel castings throughout or of steel and iron, and in various ways. Poles may be dovetailed or bolted, etc.

The rotor spider of the 65,000-kv-a. generator is cast steel throughout, made up of five sections or wheels, every wheel containing two identical castings, half wheels—Fig. 9—fastened together at each joint of the rim by two nickel steel shrink keys extending across the full breadth of rim. The half hubs are rabbeted and fastened together by numerous large nickel-steel shrink bolts. Two shaft keys, diametrically opposite and extending entire length of hub, prevent rotor turning on shaft against torque. Rotor hub at lower end rests upon a shoulder or projection of the shaft and at upper end is held in place and kept from lifting, when brakes are applied to rim underneath, by means of a circular split ring key set into shaft and bolted to hub. This multiple-wheel type of rotor spider, with circumferential spaces at the rim between adjacent wheels, insures a supply of air for removing heat from field coils. The arms of the top and bottom wheels are partly covered with steel plates to reduce windage losses and increases the flow of air through the rim.

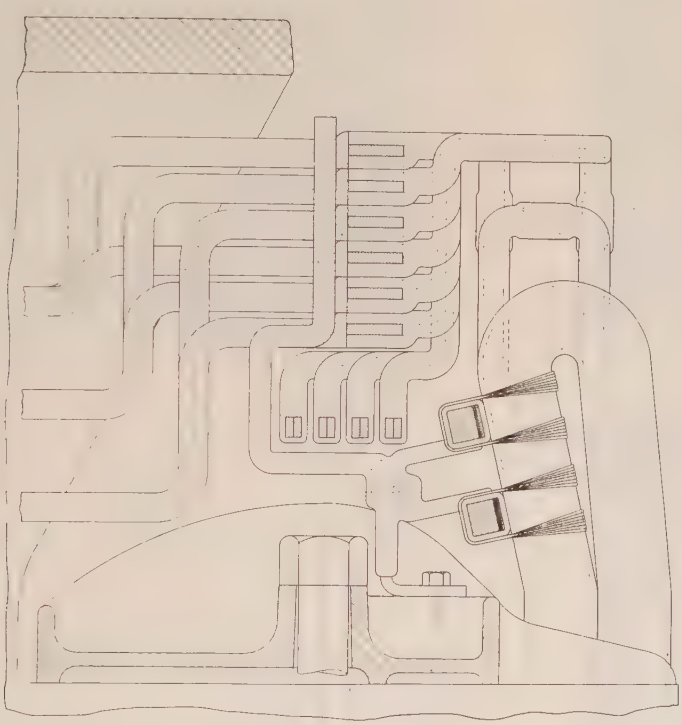

Fig. 6—Supports of Stator Winding and Connections

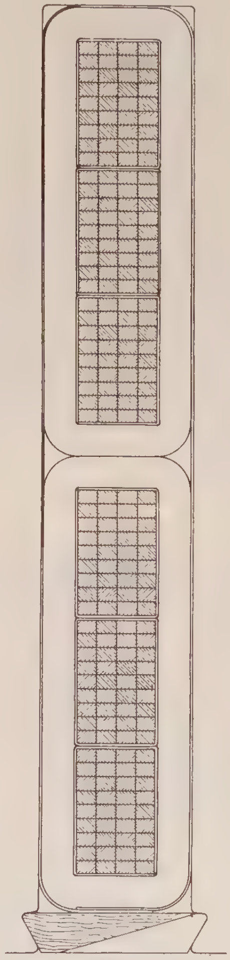

Fig. 7—Cross Section of Stator Coils in Slot

To make sure that all castings had the proper physical properties, four test coupous were cast on the rim of every half wheel. Test pieces were cut from these coupons, turned to standard size and pulled in the mechanical laboratory. The results of the tests on the forty samples from the ten castings that were

used in the rotor of the first generator, were within the limit of the contract specifications.

### Poles and Field Coils

The pole laminations are ⅛ in. thick sheet steel, clamped between heavy cast-steel end plates and securely held by large through bolts, instead of the usual rivets. Two nickel-steel keys, running the entire length of pole, including end plates, are set into pole body and tapped to receive the bolts attaching pole to rim.

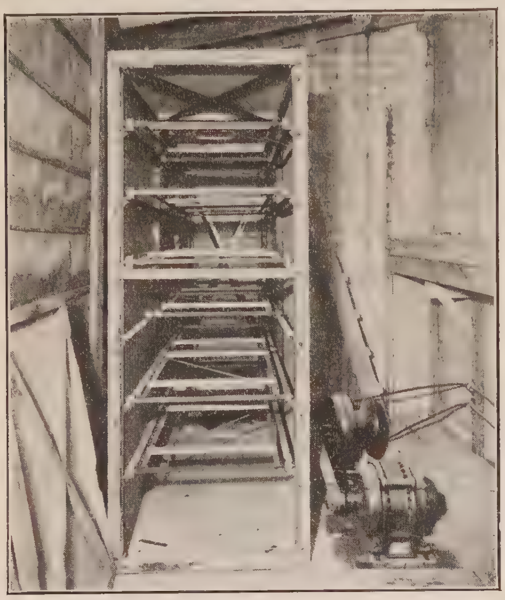

Fig. 8—Oven for Heating Armature Coils when Assembling

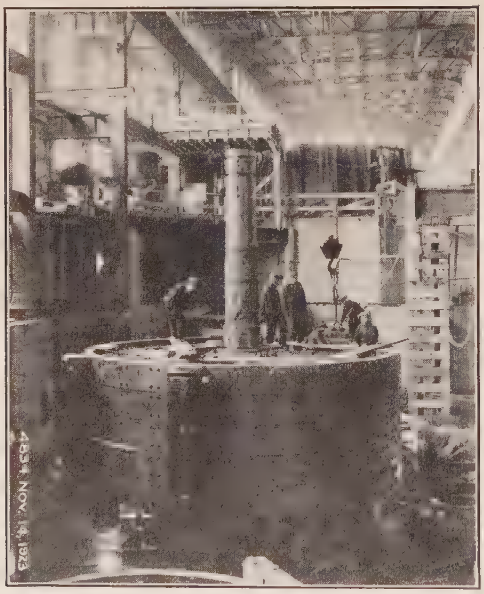

Fig. 9—Rotor Under Construction

A novel feature of this design is the method of fastening pole pieces to rotor spider. Instead of the usual dovetail, keyed type of pole, twenty nickel-steel tap bolts per pole are provided, ten the length of the pole, two in parallel, or four bolts per section of rotor rim, making a total of five hundred and sixty holes drilled radially through the rotor rim. It was thought that rotor rim casting could better be "explored" for shrink holes and checks, by drilling these radial holes as against the dovetail slot, which does not cut the rim radially. Incidentally, not one shrink hole or check was discovered when drilling the five hundred and sixty holes in all ten sections.

### Field Coils

Field coils are wound with copper strap 0.43 in. by 2.625 in. in cross section, which is probably the heaviest strap that has ever been used in field coils. It required from ten to twelve reels of copper for each coil, hence, about eleven brazings on an average per coil. The ordinary machines for winding copper strap on edge could not be used. Fortunately, a much heavier machine, used for forming field coils of the largest steam turbine generators, was available, although certain modifications were necessary. After forming coil, a special heating and clamping device was used to mould into shape for assembly on poles. The weight of copper in each coil is 2800 lb.

Rotor coil supporting brackets, insulated from coils are provided between each pair of poles, to prevent bulging of coils due to side thrust. On account of the size and weight of each pole, a special lifting device was made for lifting the pole into a vertical position when assembling. See Fig. 9. The revolving field, is guaranteed to withstand a runaway overspeed or speed test of 214 rev. per min., or twice normal, and such a test was made in the factory on each section of rotor spider and witnessed by customers' representatives. Special poles, each representing the weight of that part of pole over rotor spider section, were made up of laminations and end plates and attached to each section of rotor spider. Laminations, end plates and pole piece bolts, used in making test, were afterwards used in the assembly of the complete pole. All five sections of rotor spider passed double speed test successfully.

### Upper Bearing Bracket

The upper bearing bracket, on which rests the thrust bearing carrying an estimated load of 1,200,000 lb. is of the central-hub and separate-arm type. The central hub is a cylindrical steel casting, to which ten radial arms of cast steel are rabbeted, doweled and bolted, the whole when bolted together having a beveled turn lip at the ends of arm, fitting accurately into the stator frame for perfect mechanical alignment of bracket with stator frame, and securely fastened to the frame by large steel bolts. Bracket and bolts are insulated from stator frame to prevent "pitting" of the guide bearing, due to stray currents. The calculated deflection of 0.055 in. checks very closely with actual deflection of 0.063 in., obtained after generator was

installed. Covers are provided between arms and are partially perforated, to allow cooling air to be taken in at top of generator. Two hand holes are provided in outer portion of each cover for the inspection of stator winding and connections at any point. A platform, supported from bearing bracket for inspection of thrust bearing, is provided, and a stairway leads to this platform from upper floor of power station.

### Guide and Thrust Bearing

The upper guide bearing is centrally supported, instead of having straight seat fit, as is usual in this type of generator.

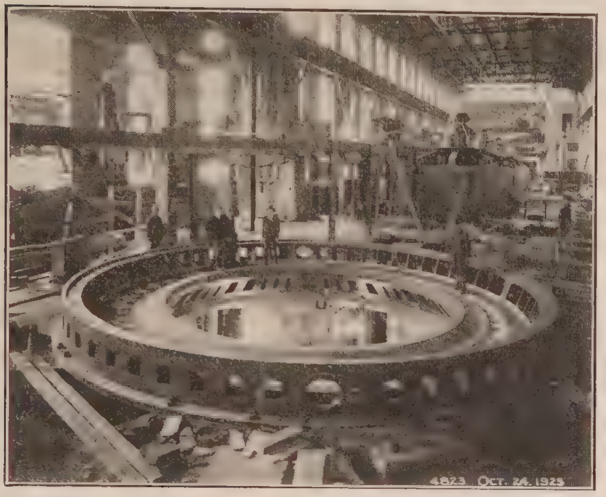


Fig. 10—Base Ring (Outer) and Brake Support (inner)

Thrust bearing is of the usual Kingsbury type, with water-cooling coils, provided for cooling the oil in the bearing housing. This bearing is designed to carry a maximum load of 1,250,000 lb.

### Base Ring and Brake Support

Another unusual feature of design is the segregation of the base ring, supporting the stator from the brake-supporting ring. See Fig. 10. Both rings are cast in four sections each, bolted together and separately grouted directly into the foundation. The brake supporting ring designed to take total weight of revolving elements, when jacks are applied under rotor rim to relieve weight on thrust bearing, besides supporting the brakes when used for shutting down. The base ring is provided with convenient man-holes for inspection of stator winding at bottom of generator.

### Collector Rings and Connections

At the upper end of the shaft a heavy cast-iron supporting shell is bolted for the two pairs of collector rings, those of main generator and those of excitation generator. The electrical connections between rings and fields are made by means of rectangular copper strips running down from rings through a hole in shaft to a point above hub of rotor, where they are joined to cables running along arms of rotor spider to field terminals. All collector connections can be made or broken inside the supporting shell. The collector rings thus mounted with supporting shell, can be easily removed and replaced. The shell also supports the speed-limiting device, at the top of which a tachometer may be placed for taking readings of speed, if required.

### Oiling System

Fig. 11 shows diagrammatic arrangement of the complete piping for each generator. A feature of design in this arrangement is that generator may be supplied directly from station system, or by separate motor-driven oil pump, acting independent of the station system. Another feature is the use of the same piping for two purposes, the application of the brakes to rotor rim to shut down (when compressed air from station system at a pressure of 150 to 200 lb. is used) and the lifting of rotor to take weight entirely off thrust bearing (when oil at a pressure of 1400 lb. per sq. in. is used). For jacking up, oil at pressure of 1400 lb. per sq. in. is supplied by a Watson-Stillman hand pump. This operation requires only a short time, and is very effective as against the more laborious method of backing off the bolts on the thrust bearing to relieve the load on bearing, when inspecting or disassembling unit.

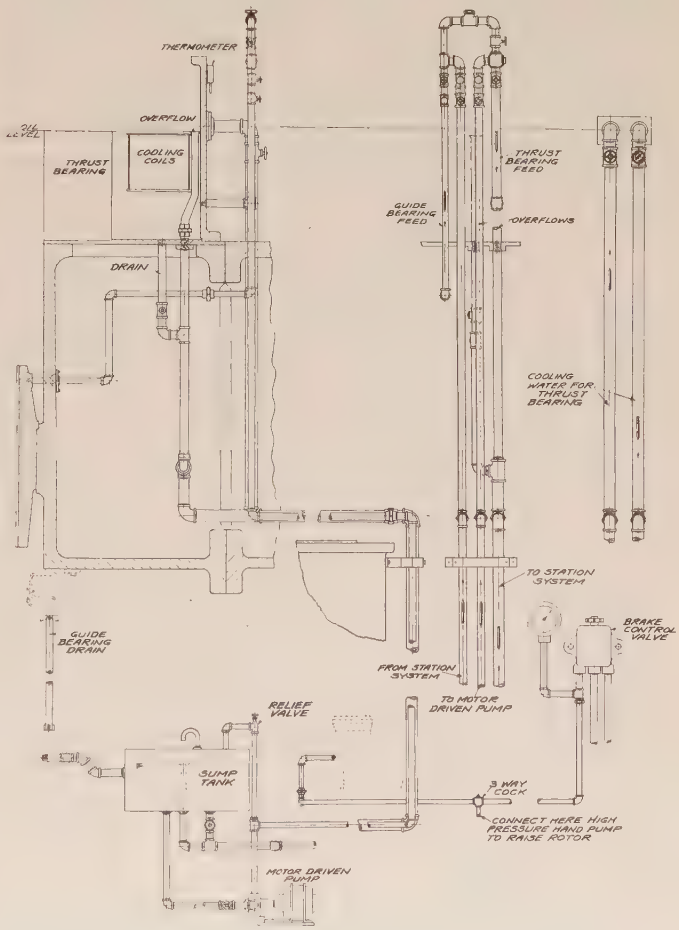


Fig. 11—Diagrammatic Plan of Piping

### Excitation Generators

A-c. generators, both steam and hydraulic driven, have of late been frequently provided with direct-connected exciters. In the case of the vertical units, the exciter is regularly mounted immediately above the thrust bearing at the top of the unit. In several of the largest and best known hydraulic plants excitation has been provided by individual motor-driven exciters, the motors being driven from a house generator or from the station system. As far as the writers know, this system of motor-driven exciters was first introduced many years ago into the plant of the Ontario Water & Power Co., Canadian Niagara Falls, at the suggestion of Mr. J. A. Johnson, who is now the electrical engineer of the Niagara Falls Power Co. Hence, it should not be considered strange that a new idea has been incorporated in this new 65,000 kv-a. generator by Mr. Johnson. A direct-connected alternator is used both for the purpose of driving the motor-generator set that supplies excitation, and also for supplying power to motor-driven auxiliaries.

Outside of the usual mounting of this generator, the stator being supported or "hung" from the bearing bracket arms and the rotor bolted directly to the rotor arms, no unusual problems of design are invloved.

### Workmanship and Installation

As a general rule, smaller generators of this type are completely assembled in the factory before shipment, to see that all parts fit together properly, and running tests are made to determine if generator comes within guarantees. Outside of assembling the rotor spider sections, without shaft, and the fitting of one or two pole pieces to determine if pole piece bolt-holes lined up with holes in rotor spider and the assembly of stairway and gallery to bearing bracket, no attempt was made to assemble this generator. Notwithstanding the fact that bearing bracket must fit stator frame accurately, that all bolt holes must line up with corresponding holes in connecting parts, that rotor spider keyways must line up accurately with shaft keyways, and all without being fitted together, when generator was finally assembled in power house for the first time, so accurately was all machine work done that, to use the words of the erecting engineer, "all parts fitted perfectly and not even one bolt had to be changed to make the assembly complete."

### Weights

| | |
|---|---|
| Stator Frame, Laminations, Windings, Flanges, etc. | 470,000 lb. |
| Stator Base Ring | 52,500 " |
| Brake Supporting Ring | 56,500 " |
| Upper Bearing Bracket | 119,150 " |
| Complete Rotor with Shaft | 783,110 " |
| Shaft | 59,432 " |
| One Rotor Pole & Winding | 10,900 " |
| Miscellaneous | 32,540 " |
| Complete Total Weight of Main Generator | 1,513,800 " |
| " " " " Excitation | 24,592 " |
| " " " " Unit | 1,538,392 " |

The $W R^2$ is 65,000,000—figures easy to remember in connection with a 65,000 kv-a. generator that has excitation auxiliary of 650 kv-a.

## AUSTRIAN RAILWAY ELECTRIFICATION

Among the various plans to substitute electricity for coal in Austria, since Austria is dependent on foreign sources for three-fourths of its coal supply, the development of water power for the electrification of railways is important. The coal needed for all steam-operated railways in Austria is estimated at 4,700,000 metric tons per year (when operating at full capacity) and this amounts to about one-fourth of the total coal requirements of the country. Over one-half of the amount of coal consumed by the railways can be saved by the utilization of electric power, much of which is yet to be developed.

In view of the present status of work the following developments may be anticipated for the next two years, according to a statement of the electrification division of the Austrian Federal Railways.

Operation of the Innsbruck-Landeck section of the Innsbruck-Telfs line was commenced in July, 1923, and a trial run was successfully made on the Telfs-Landeck section in December last. The Ruetz power plant is sufficient for present purposes, but extension of operations to Bludenz must depend on the completion of the Spullersee plant. Commencement of electrical operation on the line Stainach-Irdning-Bad Ischl of the Salzkammergut lines is expected in the early part of 1924. By the end of 1924 electrical operation of all Salzkammergut lines is looked for.

Commencement of operation on the line Innsbruck-Bludenz after completion of the Spullersee plant is to take place in 1925, but some of the trains are to be run by steam.

The cost of the entire first portion of the building program amounts to about 130,000,000 crowns ($26,000,000) as based on the estimates of the 1920 law authorizing the electrification. Since that time, the basis of calculation has changed to such an extent, owing to the approach of production and building costs to the world parity, that the sum required must be increased by about one-third. The total costs are equally distributed between the Arlberg line and the Salzkammergut lines on the one hand, and the Tauern railway and the stretch from Salzburg to Woergl on the other.

Upon completion of the contemplated building activities, 270 kilometers of Austrian federal railway lines (excluding private lines operated by the Government) will be electrified by the commencement of 1925. Partial electrical operation will result in a considerable economy of coal, as the saving for 1924 alone is estimated at 25,000,000,000 crowns, or $360,000. Further progress of the work will depend on the financing of the building program.

# Transmission Line Stability

## Analytic Deduction of the Condition for Stable Operation for Transmission Lines

BY C. L. FORTESCUE

Member, A. I. E. E.

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In the body of the paper by Fortescue and Wagner, presented at the recent Midwinter Convention, and in the companion papers by Evans and Bergvall, E. B. Shand, and Evans and Sels the conditions of stability are discussed by means of graphs. This method has been chosen as that best fitted for presenting these important factors in the problem of power transmission before the engineering public in the form best adapted for practical application.

As is usually the case, these methods, since they have to deal with special cases, lose in generality and, in addition, a certain conciseness and simplicity is present in the analytic solution which is lost in the solution by means of graphs. This is plainly seen, as a single expression gives the conditions of power transmission stability and applies to any system of power transmission.

The conditions for stability given in this article were originally arrived at by a method of analysis similar to that given below, but the method of reasoning was not so general as the one presented, which was suggested by a discussion with Dr. Slepian. This problem of power transmission stability was first brought to the writer's attention by the work of Evans and Sels, part of which was given in the A. I. E. E. JOURNAL. In frequent discussions with them, the conclusion was arrived at that the maximum power limit, as indicated on the circle diagram, was not the true power limit. Evans and Sels at that time felt that the point of tangency of the circle locus and the envelope was of importance in connection with the problem and they also suspected that the size of the condensers had some influence. We shall see that this surmise was true.

The writer and his associates arrived at the true conditions for stable power transmission with loads having the characteristic of being dependent on frequency only. This relation was worked out about the same time that the tests described in the paper by Evans and Bergvall were initiated, and was the final confirmation of the writer's belief in the inherent practicability of the Baum system.

The tests verified the mathematical solution, that is to say, instability did actually occur at the point indicated by the analytic solution. These results were obtained by plotting the graphs for constant power of the transmission line and constant excitation of the synchronous condenser and marking the point at which the condensers pulled out. This was found to be always at the point of tangency of two members of the two systems of graphs, which represented the condition of operation on the instant of pull out.

The analytic deduction of the conditions of stable operation of a transmission line follows.

We shall confine our attention at first to a straight transmission line, consisting of generating apparatus at one end and a load at the other end. The voltage at both ends of the line may be assumed constant, though as we shall see, this is not a necessary condition for the success of the analysis. We shall also at present consider only the static conditions of stability, that is, leaving out the effects of inertia of rotating apparatus. This is a mathematical artifice frequently used to simplify a problem and in no way vitiates the results, provided that the premises are understood, and is well known in dynamics.

Assuming the power load at the end of the line to be $P$, that the voltage at this point is $E$ and that the synchronous condensers are excited to a voltage corresponding to $E_x$ on open circuit $Q$, the amount of reactive power required by the line to maintain the voltage $E$ and that supplied by the condenser may be expressed by the two equations

$$Q = f\,(P \quad , E) = Q_r \tag{1}$$

$$Q = g\,(E_x \quad , E) = Q_s \tag{2}$$

These two equations merely express the relation that, as far as this problem is concerned, $Q$ is a function of the power delivered and the terminal voltage in the case of the transmission line, and of the voltage of excitation $E_x$, and $E$ as far as the synchronous condenser is concerned.

From (1) and (2) we have

$$\delta Q = \left(\frac{\partial Q_r}{\partial P}\right)_{E\,const.}^{\delta P} + \left(\frac{\partial Q_r}{\partial E}\right)_{P\,const.}^{\delta E} \tag{3}$$

$$\delta Q = \left(\frac{\partial Q_s}{\partial E_x}\right)_{E\,const.}^{\delta E_x} + \left(\frac{\partial Q_s}{\partial E}\right)_{E_x\,const.}^{\delta E} \tag{4}$$

It will be observed from this equation that if $\delta E$ is arbitrary, that is under our control, there is always a mathematical solution. In particular, if we can maintain $E$ constant, that is, $\delta E$ equal to zero, we shall

*This article is presented as a supplement to the paper by Fortescue and Wagne rentitled "Some Theoretical Considerations of Power Transmission" presented at the Midwinter, Convention, February 4, 1924.*

have the condition of operation contingent on the relation.

$$\left(\frac{\partial Q_r}{\partial P}\right)_{E_{const.}}^{\delta P} = \left(\frac{\partial Q_s}{\partial E_x}\right)_{E_{const.}}^{\delta E_x} \tag{5}$$

which since $\frac{\partial Q_r}{\partial P}$ is positive up to the maximum limit for $E$ constant, where it approaches infinity as a limit, it means that with a finite condenser an infinitely wide range of excitation would be required to enable us to reach this limit, or we might approach this limit if $\frac{\partial Q_s}{\partial E_x}$ were extremely large, which means in ordinary language an extremely large condenser.

In actual practise we must deal with things as they are, and not befuddle ourselves with mathematical fictions. We have to take account of three things in our control apparatus:

(1) Our condensers are limited in size for economic considerations.

(2) Our range of excitation is also limited for similar reasons.

(3) Our regulating devices do not operate to anticipate a result, but use the result to bring factors into play to counteract it.

In dealing with power problems we must, therefore, consider the conditions in these condensers, as far as excitation is concerned, as remaining unchanged, as there is an appreciable lapse of time before the regulator begins to operate and there is a further lapse of time before the condenser field begins to build up. In our equations (3) and (4) for actual conditions, we must assume $\delta E_x$ to be zero, we therefore have

$$\delta Q = \left(\frac{\partial Q_r}{\partial P}\right)_{E_{const.}}^{\delta P} + \left(\frac{\partial Q_r}{\partial E}\right)_{P_{const.}}^{\delta E} \tag{5}$$

$$\delta Q = \left(\frac{\partial Q_s}{\partial E}\right)_{E_{x const.}}^{\delta E} \tag{6}$$

Eliminating $\delta Q$ the conditions for a solution must therefore be

$$\left(\frac{\partial Q_r}{\partial P}\right)_{E_{const.}}^{\delta P} + \left\{\left(\frac{\partial Q_r}{\partial E}\right)_{P_{const.}} - \left(\frac{\partial Q_s}{\partial E}\right)_{E_{x const.}}\right\}\delta E = 0 \tag{7}$$

This equation expresses the condition for stable operation in its simplest form. It is a relatively simple matter to bring in other influences such as the voltage at the sending end of the transmission line and the load characteristics of the generators and of the prime movers, but since the object of these papers and this discussion is to illustrate the conditions that must be met for successful operation of practical transmission lines, rather than to give a vigorous mathematical solution of the problem, we shall retain the simple form given in (7), only pointing out how the other factors, when taken into account, will affect the solution.

In an ordinary transmission line the quantity $\left(\frac{\partial Q_r}{\partial P}\right)_{E_{const.}}$ is always positive up to the maximum power limit, at which value it approaches infinity as a limit. $\delta P$ may be assumed arbitrary for ordinary cases where the load is increased by increasing the admittance, as, for example, in ordinary induction or synchronous motors driving mechanical loads and so forth. Furthermore, any such increase in load must be accompanied by a decrease in voltage so that $\delta E$ is always a negative quantity when $\delta P$ is positive. Therefore, in order that the "conditional equation" (7) shall be satisfied

$$\left(\frac{\partial Q_r}{\partial E}\right)_{P_{const}} \text{ must be } > \left(\frac{\partial Q_s}{\partial E}\right)_{E_{const.}} \tag{8}$$

The limit of stability for exceedingly small increments of load $\delta P$ is reached when

$$\left(\frac{\partial Q_r}{\partial E}\right)_{P_{const.}} = \left(\frac{\partial Q_s}{\partial E}\right)_{E_{x const.}} \tag{9}$$

$$\left(\frac{d P}{d Q}\right)_{E_{x const.}} = 0 \tag{10}$$

This latter is one of the conditions demonstrated by means of graphs in our paper. The condition (9) was obtained originally by a similar method of analysis as that given above and was also arrived at independently as a result of analyzing the test result. It is the condition that a particular member of the family of condenser curves $E_x$ = constant shall touch a particular member of the family of transmission line curves $P$ = constant.

In a transmission line the family of power circles $E$ = constant gives $\left(\frac{\partial Q_r}{\partial E}\right)_{P_{const.}}$ always positive with increasing $P$ until they touch the envelope, when its sign becomes negative. For the power circles that do not touch the envelope, this quantity is always negative. For a synchronous condenser $\left(\frac{\partial Q_s}{\partial E}\right)_{E_{x const.}}$ is always negative within the limits of its field excitation.

As a consequence, for a transmission line having such characteristics that its power circle touches the envelope, the operation is essentially stable and independent of the synchronous condenser characteristics, until the value of power corresponding to the point of

osculation is reached, from which point on, its stability depends on the characteristics of the condenser. I shall show later on another way of interpreting these results, after I have indicated another possible way of operating a transmission line.

For a transmission line which has such characteristics that its power circle for the operating voltage falls within the envelope, the condition of operation is inherently unstable, since it depends altogether on the characteristics of the condenser to maintain its voltage during the transition stage, while the regulator comes into play. As the point of actual instability is approached, a small increment of load will produce a large drop in voltage until the regulators come into play. A transmission line of this type is therefore undesirable for super-power transmission.

Let us apply the "conditional equation" (7) to another type of load which may be termed a dead load, such as that obtained by loading with non-inductive resistance. In this case we are not at liberty to assume $\delta P$ as positive when the resistance is decreased. Such a change in resistance during the transition stage may result in a lowering of the power delivered; but in this case also $\delta E$ will be negative. Under these conditions, therefore, there is no tendency to instability, for a solution may always be found for the transition period when $\delta P$ may be taken as negative. It must be remembered, of course, that after the regulator has completed its operation, the value of power will be increased. What happens is that the voltage drops faster than the current increase during the transition period. This is one of the operating conditions discussed by means of graphs in our paper.

Let us next consider the character of operation where static condensers are used to regulate the line voltage. It is assumed that a voltage regulator is used to throw condensers on the circuit as the load condition demands. We have, therefore, the same conditions to contend with as in the synchronous condenser, that is to say, an appreciable time must elapse before the additional condensers required for a load change are thrown on the line. The characteristics of a condenser are such that

$$Q = 2^{\pi} f\, c\, E^{s} = Q_s$$

and therefore $\dfrac{\partial Q_s}{\partial E}$ is always positive, that is, $Q$ increases and decreases with $E$. Therefore, in equation (7) the limiting condition expressed by (9) is reached very much sooner than with a synchronous condenser and occurs before the power circle touches the envelope. What occurs in this case is the voltage tends to slump to a low value. The saving factor is the fact that all loads have rotating apparatus with characteristics similar to those of synchronous condensers, but if a constant power load could be maintained during the transition period without any change in power factor, the voltage would actually slump to zero, unless the regulator came into play quickly enough to increase the amount of capacity.

It would not seem advisable therefore at the present stage to consider the use of static condensers alone for regulating purposes, without giving careful consideration to the extent to which they limit the amount of power that can be delivered over the line, due to their effect on connected rotating apparatus.

In the case of dead loads, such as non-inductive resistance would make, there is always a solution for the transition stage at the lower value of voltage because $\delta P$ may in such a case be negative. $\delta E$ is always negative for an increase in load admittance. $\delta P$ at one stage is positive, becomes zero as $P$ increases and then negative. That is to say, at some stage before the point of osculation with the envelope is reached a decrease in resistance will result in a decrease of power.

Let us now interpret equation (9) for another possible method of operating a transmission line, that is, at constant current instead of constant voltage. In this case when $\delta P$ is positive $\delta E$ will also be positive and the stable conditions of operation will occur when

$$\left(\frac{\partial Q_r}{\partial E}\right)_{P\,const.} \text{ is less than } \left(\frac{\partial Q_s}{\partial E}\right)_{E_x\,const.} \quad i.\ e., \text{ the}$$

range of stable operation considered on the basis of the $E$ constant power circles will be on the portion of these circles which gives no practical solution for constant potential transmission. That is the same as saying that the constant voltage systems and the constant current systems of operation are complimentary systems. Another condition that may be noted is that the static condenser characteristics are the characteristics that best lend themselves to constant current operation, just as the synchronous condenser characteristics are those that best lend themselves to constant voltage operations.

We may therefore say that for constant potential operation the designs and loading of transmission lines best adapted are those which have constant potential characteristics and these are found in the lengths of lines at spacings between stations that give power circles at this operating voltage, which touch the envelope curve at values above the operating range. Beyond the point of osculation the characteristics of the transmission line approach constant current characteristics in their behavior. Very long transmission lines tend to approach constant current in characteristics.

Let us now consider the conditions of stability of a transmission line having more than one section. Let us consider what happens if the power $P$ is increased by $\delta P$. We shall have at once a drop in voltage at the receiver and $\delta E_1$. This will be instantly followed by a drop of voltage at the terminals of the inter-

mediate condenser, so that the equation of condition (7) must contain an additional term $\frac{\partial Q_r}{\partial E_2} \delta E_2$. This term will affect the load at which instability takes place, in a manner similar to $\delta E$, and will therefore cause pull out to take place at a lower load.

On the other hand, it is quite evident that when the load is placed at the intermediate point, the effect of the additional section of line with its condenser will be such as to increase the amount of power that may be taken off before reaching instability. That is to say, the additional section must be reckoned as if it were the equivalent of increased capacity in condensers.

The preceding arguments apply equally well to a Baum transmission line of any number of sections and it will be observed that the condition of stability of any given section involves merely the terminal voltages of that section. Of course, a load at any given point may cause instability at some other point, due to a section having a terminal at that point, having reached its stability limit as a consequence of the load at the first point. This is, however, well recognized and the stability relations of any section of the transmission line, no matter where the load is taken off, is subject to the same governing conditions.

A factor which has considerable bearing on the stability of the system, is the inertia of the condensers, generators and prime movers. In general, these factors tend to delay the system from falling out and give the regulating apparatus a chance to save the situation. However, there are exceptions to this in the case of the generating apparatus and prime mover where high inertia may prove at times detrimental.

Suppose we have a transmission line fed from a hydro-electric power house tied in with a large steam generating system. What will be the action when a sudden load is thrown on the common distribution system?

The receiver end of the transmission line proceeds at once to lag. The rate at which this takes place depends on the amount of the change of load and the inertia of the synchronous condensers, which, in changing phase, deliver power to the load. If there are intermediate stations, these also will change their angular positions until the whole integrated change in phase is carried up to the generator.

Let us now see how the generator will behave. In the first place, since each synchronous station adds to the angular displacement the generator has to go through, the latter will be able to deliver a large amount of energy, due to its own inertia and that of the hydraulic turbine and the water flow. It is desirable that during this transition period the rate at which this energy can be delivered will never cause the amount of power transmitted to exceed the power limit of the transmission system.

The hydraulic turbine, being a constant torque machine, can deliver no more power than the original value before the change in load, provided the gates remain unchanged, and therefore the transmission system, including the generators, will fall back in phase, refusing to deliver more power to the common distribution system than that originally delivered, plus the amount given up, due to the rate of decrease of momentum of the generators, hydraulic machinery, water and synchronous condensers. As a consequence, the whole transmission system will change in angular relation to the steam system in such a way as to help out the steam system by delivering wattless power to it, rather than additional power and this again will assist the steam station in picking up the additional load. The steam governor, of course, functions towards the same end. Thus it will be evident that the tendency of the hydroelectric transmission system is to relieve itself, maintaining its own stability, throwing on the steam station the burden of meeting any rapid fluctuations in load.

There is, therefore, a decided advantage in having the governor of the hydraulic static sluggish in operations, and it suggests further that the governing device should be controlled so that it will hold the speed constant up to a certain delivery of power, which should be determined on the basis of the maximum power that can be delivered over the transmission line without incurring instability.

If the transmission system cannot reach a condition of stability on this basis, it will have a tendency to deliver an increasing amount of wattless power to the steam system until instability is reached, due to this fact and not on account of the power delivered over the transmission lines.

The above is a simplified analysis of the conditions determining stability of a transmission line. This simplified analysis has been confirmed by actual tests. Under other conditions it may prove that the various factors that have been ignored will have some influence, and it is proposed at some future time to extend the anaylsis to take these additional factors into account.

The results of these tests and the analysis given in the papers and in the article indicate that in using the Baum system the development of super-power lines at 220,000 volts may be undertaken with perfect confidence, the stability limit being well defined and the value being determined by the spacing of the substations. It is expected that future tests will be made on actual operating systems.

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Electric power will be used to operate a new iron and steel plant to be constructed by the Brazilian Government in the Doce River valley in the State of Minas Geraes. This is one of three plants being erected under the terms of a decree promulgated January 19, 1924.

# Carrier Telephony on Power Lines

BY N. H. SLAUGHTER
Member, A. I. E. E.
and
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Both of the Western Electric Company

WHILE the use of power lines as the transmission medium for telephone currents is a comparatively recent development, the fundamental problems involved and the methods employed do not differ essentially from the somewhat older arts of multiplex or carrier telephony over telephone lines, and radio telephony. The differences lie chiefly in the range of carrier frequencies which is best adapted to each scheme, and the means which are employed to connect the telephone equipment to the transmission medium.

In any telephone system, the fundamental requirements are as follows:

a. The operation from the user's standpoint must be reliable, simple and safe, the received signal must be of ample volume, free of disturbing noise, and a sufficiently faithful reproduction of the original sound to be clearly understandable.

b. The maintenance of the equipment must be simple, so that an excessive amount of neither time nor skill is required to keep the system in operation.

c. The cost of the equipment, both as regards investment and operation charges, must be such that it is at least as economical as other methods of accomplishing the same result.

When these fundamental requirements are interpreted in terms of the particular problems encountered in the design of carrier equipment for power lines, it is found that there must be provided, from the transmission-engineering standpoint, sufficient amplifying capacity to care for both normal and abnormal losses in transmission. Distortion of the wave form of the speech waves must be kept small, and sufficient selectivity must be provided to completely separate the desired frequency bands from the undesired ones. The carrier equipment must be well protected from accidental exposure to the power-line voltage. Duplex operation (without push-button control) similar to ordinary telephone practise, should be provided, as well as selective signaling. The equipment must be so designed as to be cheap to manufacture and easy to install, operate and maintain.

A knowledge of the transmission characteristics of power lines and associated power apparatus at carrier frequencies is necessary for the understanding of the transmission problems peculiar to power-line carrier-telephone systems.

While the theory and practise developed in connection with commercial telephone systems both at voice frequencies and at the higher frequencies employed by multiplex-carrier telephone systems on telephone lines[1] have made it possible to predict the order of magnitude of the characteristic[2] or surge impedance and the attenuation of the line alone, it has seemed desirable to check the computed values with actual measurements, made in accordance with methods employed in telephone transmission engineering. These measurements also include the effect of grounded guard wires and the power equipment associated with transmission lines, which is more difficult to predetermine.

In Fig. 1 is shown a curve of the ratio of received current $I_R$ to transmitted current $I_T$, plotted against frequency, for a power-transmission line of 100 miles[3] in length.

This curve is plotted from experimental data obtained on an actual 110,000-volt line, the line being free of all power equipment. The use of this ratio of output to input current, as a measure of the power loss in the transmission line, is, of course, predicated upon the assumption that the line is uniform and is terminated at each end in its characteristic impedance.

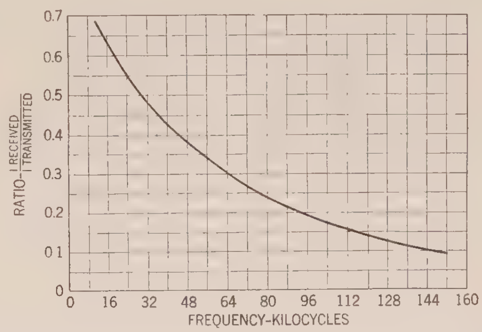


FIG. 1—ATTENUATION OF A TYPICAL POWER TRANSMISSION LINE OF 100 MILES IN LENGTH AT CARRIER FREQUENCY

Although the exact attenuation of a line is dependent upon the geometry, leakage resistance, conductance

1. Article of E. H. Colpitts and O. B. Blackwell, A. I. E. E. PROC., Vol. 40, pp. 301-315, 410-421, 517-526.

2. The characteristic or surge impedance ($Z_0$) of a transmission line may be defined as the impedance of an identical line of infinite length. It may be determined on a line of finite length by application of the formula

$$Z_0 = \sqrt{Z_{open} \times Z_{short}}$$

where $Z_0$ = characteristic impedance
$Z_{open}$ = impedance of open-circuited line
$Z_{short}$ = impedance of short-circuited line

3. This curve may be reproduced for lines of a length $L$ different from 100 by the following formula.

$$I_{rec}/I_{trans} = \frac{1}{\log^{-1}(L/100 \log X)}$$ for any freqeuncy $f_1$, where $10{,}000\ f_1 < 150{,}000$ cycles where $X$ = the reciprocal of $I_{rec}/I_{trans}$ as obtained from the curve

*To be presented at the Spring Convention of the A. I. E. E., Birmingham, Ala., April 7-11, 1924.*

and other factors, the values given in Fig. 1 may be applied to most 110,000-volt transmission systems in this country to obtain approximate values of attenuation.

The experimental data are at present meager but it seems probable that the effect of grounded guard wires may be ignored in calculating the approximate attenuation of high-voltage transmission lines.

In Fig. 2 is shown the impedance versus frequency characteristics of a typical 6600 to 110,000-volt transformer. Two curves are shown, one representing impedance with the primary open and the other with the primary short-circuited. These curves are erratic between 10,000 and 50,000 cycles showing the presence of resonant effects. However, above the latter frequency, the curves coincide and the shape of the curve indicates that the impedance is determined by the distributed capacity of the winding. The coincidence of these curves leads to the conclusion that above 50,000 cycles the impedance of the transformer is independent of the apparatus connected to the low-potential side.

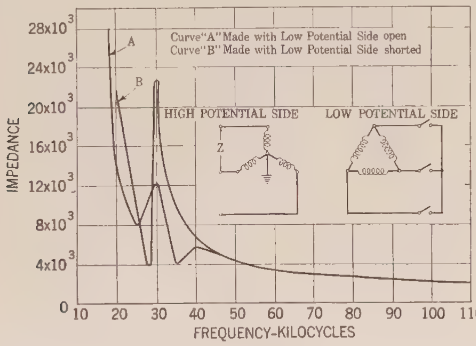


Fig. 2—Impedance Characteristics of a Typical 6600: 110,000-Volt Transformer Bank at Carrier Frequencies

The information contained in Figs. 1 and 2 gives us a basis for determining the characteristics of a transmission line and its associated power apparatus. Knowing the length of a particular line, and the extent and location of power equipment connected to it, it is possible to arrive at an approximate value of the attenuation of the system. This point, however, is not as important as the other conclusions which may be drawn from a study of the line and transformer characteristics.

Since the attenuation of the line alone is smooth and not excessive for frequencies below 150,000 cycles, it is apparent that from the standpoint of this attenuation, the frequency employed is relatively unimportant. However, a study of the characteristics of power transformers indicates that for frequencies below 10,000 cycles these transformers act as transformers and introduce large carrier-frequency losses, due to the transfer of carrier-frequency power to the low-potential network. For frequencies between 10,000 and 50,000 cycles resonant peaks are likely to occur, resulting in excessive attenuation for particular frequencies, while above 50,000 cycles, neither of these objections applies.

In selecting the frequency band best suited for carrier telephony on power circuits, the characteristics of both the line alone and the transformers indicate that the use of frequencies in the band between 50 and 150 kilocycles will result in satisfactory operation. From the standpoint of interference, this frequency band is also desirable. The frequencies are too high to interfere with commercial telephone systems since the present limiting frequency for multiplex systems is about 35,000 cycles; and they are too low to interfere with broadcasting or marine radio communication. They are, however, in the band of frequencies employed for certain classes of radio telegraph service.

From the standpoint of coupling the carrier equipment to the power line, this frequency band proves again to be desirable, since coupling by means of capacity becomes easier as the frequency is increased.

In the development of this carrier equipment, it was early decided to employ a full metallic high-frequency circuit rather than a ground-return circuit. The trend of the communication art has always been away from ground-return circuits because the attenuation of ground-return circuits is greater than that of comparable full metallic circuits. As the ground connection itself is unstable, such a circuit is subject to interference from other ground-return circuits and will itself produce interference in adjacent communication circuits. In addition to these objections, a ground-return circuit is generally noisy, particularly when it is associated with power equipment.

The provision of proper means for connecting a carrier telephone circuit to the high-voltage transmissoin lines is one of the most difficult problems involved. The coupling device must offer a safe and efficient means for transferring high-frequency energy to and from the power lines.

The use of inductive coupling did not seem feasible since it required a special transformer having a 60-cycle difference of potential between windings of approximately 65,000 volts on a 110,000-volt line. The use of existing power transformers to secure this coupling is not feasible because they do not act as transformers at the carrier frequencies.

The capacity coupling seemed to offer the most feasible solution of the problem. The first type of condenser considered was the capacity secured between a single wire parallel to the power-line conductor and the conductor itself. This type of condenser has two fundamental weaknesses. In the first place, it has what is known as distributed capacity and in the second place, its capacity to ground is generally larger than the capacity to the power conductor. The use of this form of condenser lends itself best to a tuned circuit, similar to that employed for radio-transmitting circuits. The major part of the energy which in a radio-transmitting circuit would be radiated into the ether is transferred from the antennas to the power-line conductor by virtue of the capacity existing between them. There are two

serious objections to this type of circuit, the less serious objection being that since it is a tuned circuit, the frequency band which can be transmitted is very narrow which makes this arrangement not so well adapted to duplex operation as the filter arrangement described below. The second objection is the fact that a portion of the energy delivered to the antennae is radiated and may be picked up by a suitable radio receiving set. Since secrecy is not a primary object of this type of communication, this would not be objectionable but for the fact that it may require the licensing of carrier equipment by the Government and its operation by licensed radio operators. From the standpoint of reception, this type of coupling is also undesirable. It has many of the characteristics of a radio receiving set and will readily pick up radio signals lying in its frequency range. The use of concentrated capacity, such as in an ordinary fixed condenser, avoids these difficulties, but it introduces the problem of insulating the condenser plates. The development of a satisfactory condenser has been undertaken by a well-known manufacturer of power-line equipment, and this con-

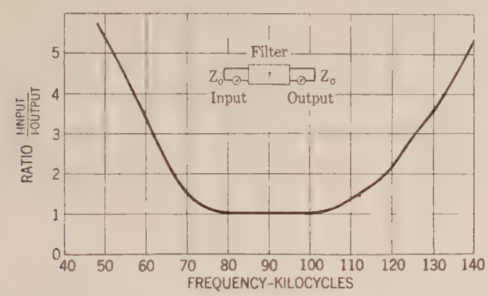


Fig. 3—Attenuation Characteristic of a Band Pass Filter Similar to that Shown in Fig. 6

densor will, no doubt, be available for all commercial installations.

The coupling capacity may be employed either as a part of a series-resonant circuit or as part of a filter circuit. The former lends itself to the transmission or reception of a narrow-frequency band but is not efficient for the simultaneous transmission and reception of signals of two different frequencies. Filter circuits[4] can be designed to pass a relatively wide band of frequencies with a small attenuation. The filter also simplifies the problem of static 60-cycle charges since it provides a path to ground for low frequencies without grounding the high-frequency circuit. Fig. 3 shows the characteristic of a band-pass filter, suitable for use as a means of coupling the carrier currents to the power line.

The power required for telephone transmission over power lines is largely determined by the magnitude of the disturbing currents or "noise" which are of frequencies in the range of the carrier equipment. If no "noise" were present the carrier transmitter would not be called upon to increase the power delivered by the telephone transmitter, but would have to merely change the frequency band. The receiving equipment would then furnish all the amplification needed to counterbalance losses in transmission over the system. However, in actual practice noise exists in the form of more or less infinitesimal electrical disturbances at all frequencies, the level of this noise generally decreasing as the frequency increases.

Based on a knowledge of noise conditions on transmission lines and with other practical considerations in mind, the receiving gain has been limited to a voltage amplification of about 100, which corresponds to a power amplification of about 10,000. Since it is desirable to deliver about 0.01 watt to the telephone receiving circuit, a carrier-frequency power as low as 0.000001 watt at the input to the receiving circuit will produce satisfactory results under favorable conditions. To allow for less favorable conditions, it is assumed that a power of 0.00001 watt is required. Based upon this assumption and the curve given in Fig. 1, it is evident that an output of one watt from the transmitting circuit is sufficient for operation over 265 miles of transmission line, when the carrier frequency is 150 kilocycles and there is no loss in the coupling device or the associated power equipment. Actually, the loss due to other transmission lines connected to the line on which the carrier is operated, the loss in power equipment, and loss in the coupling device, may reduce this normal range to 100 miles or less. It seems probable, therefore, that a relatively small output from the transmitting circuit will be sufficient for normal operation on the majority of transmission lines.

However, when emergencies arise, telephone service is of the utmost importance, and, therefore, a larger transmitting output should be available, sufficient to insure satisfactory operation under unusual line conditions and actual line failures.

In order that duplex operation may be secured, it is necessary to operate the transmitting and receiving circuit simultaneously, which means that the receiving circuit, designed to operate on an input of 0.00001 watt, must operate in parallel with the transmitting circuit which may deliver as much as 50 watts to the power line. This large power ratio makes the separation of the transmitted and received currents a difficult problem, which has been solved only because of recent progress in the art of designing electrical filters. By employing frequencies for transmitting and receiving, which differ by about 20,000 cycles, it is possible to prevent the transmitting circuit from interfering with the receiving circuit. For this purpose, a high-pass filter and a low-pass filter, similar to those described in recent literature, are employed.[5] The high-pass filter passes frequencies above 100,000 cycles and attenuates frequencies below that frequency, while the low-pass filter

4. U. S. Patents 1,227,113; 1,227,114 of 1917.
G. A. Campbell, Wave Filters for high frequencies.

5. G. A. Campbell, B. S. T. J., November, 1922.
O. J. Zobel, B. S. T. J., Vol. 11, No. 1, pp. 1-46.
O. J. Zobel, J. H. Carson, B. S. T. J., Vol. 11, No. 3, pp. 1-52.

passes frequencies below 80,000 cycles and attenuates frequencies above 80,000 cycles.

Fig. 4 is a block schematic diagram of a carrier telephone system, developed for use on high-voltage power lines. The design of this equipment, both electrical and mechanical, has profited by the research and development work in connection with the arts of communication at speech frequencies, carrier frequencies, and radio frequencies.[6] As a result, the circuits employed and the equipment used in these circuits have the background of wide experience.

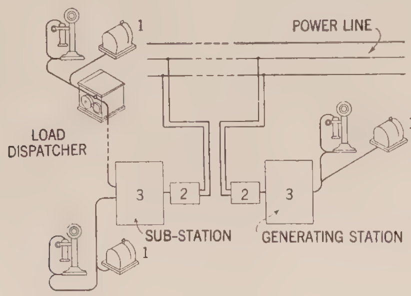


Fig. 4—Power Line Carrier Telephone System
1. Ringing Keys
2. Coupling Devices
3. Carrier Equipment—See Fig. 5

The transmitting circuit comprises an oscillator-modulator circuit which will provide sufficient output for operation on the majority of power lines. The circuit also provides a power amplifier which may be connected in the circuit by a simple operation, for use in emergencies. The operation of the circuit, while employing the 50-watt power amplifier, is in no way different from the operation without the amplifier. The transmitting circuit is entirely automatic in its operation, and is energized only when the circuit is in use.

The receiving circuit consists of a two-stage high-frequency amplifier followed by a negative grid detector. There is no tuning required in this receiving circuit. The circuit is not regenerative, this having been avoided because of the lack of stability in circuits of this type.

Signaling on this carrier circuit is entirely automatic and where more than two stations are involved, it is selective. The operation of the ringing key sends out a predetermined train of pulses at the carrier frequency. These pulses, when received and rectified, operate a selector of a type commonly used for telephone dispatching on railroad lines.

The voice-frequency telephone circuits are standard circuits suitable for either two-wire or four-wire operation. The circuit may be extended to a telephone located at a point several miles from the carrier equipment with full control of the carrier, as is desirable in the case of the load dispatcher, or without control of the carrier; that is to say, where the load dispatcher is located at a point some distance from the carrier terminal, he may be provided with the same control and talking facilities as for the terminal proper. After considering the relative merits of the control arrangements, employing the talking circuit for control purposes also, as compared with a separate pair of wires for the control circuit, it has been decided that the separate-control circuit results in a much simpler and more reliable arrangement. Accordingly four wires, two for talking and two for control are required. (See Fig. 5). Where it is not desirable to provide control of the carrier equipment, the talking circuit may be extended through a standard *P B X* board in a manner similar to that employed for ordinary wire-telephone circuits. Two or more carrier systems of this type may be operated in tandem where circumstances make it possible and desirable to do this. No special equipment is required in extending the carrier circuit in any of the above ways.

The power supply for the carrier equipment may be obtained from any source which is convenient. The tube filaments require 24 volts d-c. and a current drain of only a few amperes, which can ordinarily be supplied best from storage batteries. The plate circuits of the receiver and the low-power transmitter require 150 volts d-c., with a current drain of a fraction of one ampere. This can be obtained from storage batteries, or a motor-generator driven from the 24-volt supply required for the filaments. The high-power transmitter requires 800 volts d-c., for plate potential and this can be obtained best from a 150-watt motor-generator set driven from the 24-volt source. This provides a power

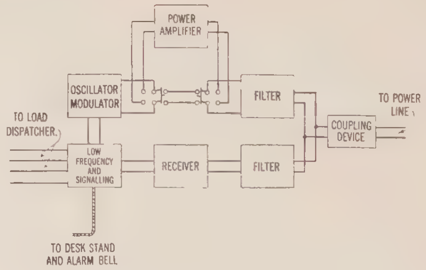


Fig. 5—Block Schematic of a Power Line Carrier Telephone Terminal

supply independent of the transmission line, an important point where transmission line failures or interruptions of power supply from other causes are likely to occur. Where the latter consideration is not important, both the 150 volts d-c., and 800 volts d-c. may be secured from a-c. rectifiers.

The vacuum tubes employed in this equipment are standard tubes, familiar in telephone and radio practise. The average life of the tubes employed in the receiving circuit is about 10,000 hours which is equivalent to continuous operation for a little more than a year.

6. H. W. Nichols—Lloyd Espenschied, I. R. R. *Proc.* Vol. II, pp. 193-239, June, 1923.

Lloyd Espenschied, I. R. E. *Proc.* Vol. 10, pp. 344-368, October, 1922.

L. M. Clement, F. M. Ryan, D. K. Martin, I. R. E. *Proc.* Vol, 9. pp. 469-505, December, 1921.

Some of the tubes in the transmitting circuit have a shorter life but since they are not continuously operated, replacements will not be necessary on the average more than once a year.

The protection of the personnel operating the carrier equipment, and the carrier equipment itself, from the high voltages employed on the power line is of vital importance. In Fig. 6 is shown diagramatically the method employed in coupling the carrier equipment to the power line. The condenser (3) may be a fixed condenser or the distributed capacity secured by suspending a wire parallel to the power-line conductors. In either case, this condenser is designed and tested so that it has the accepted factor of safety required for work of this character. In event of a failure of this condenser, a momentary short-circuit current flows through the fuse (4) to ground at (1). The reactance shown, connecting this condenser to ground, is negligible at power frequencies since its inductance is a fraction of 1 millihenry. In spite of the low inductance of this coil, it is possible that an appreciable voltage may be developed across it and, therefore, heavy-duty static spark gaps, having about ¼-in. clearance, are connected across this coil. On the carrier-apparatus side of this coil the fuses, vacuum gap and air gap commonly used for protection of wire telephone circuits paralleling high-voltage power circuits, are used and as a final measure of protection, a high-voltage mica condenser ($S$) separates the coupling device from the carrier equipment. This circuit has been laid out to secure the maximum possible protection both from static-power potentials and from conditions which may arise because of the failure of the coupling condensers. The fuse shown at (4) is designed to break the power arc at the line potential.

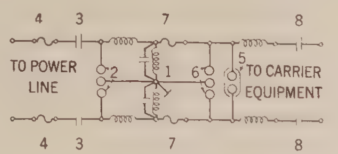


Fig. 6—Band Pass Filter Suitable for Coupling a Carrier Telephone System to a Power Transmission Line

This Equipment may all be Outdoors:
1. Low Resistance Coil with Mid-Point Grounded
2. Heavy Duty Static Spark Gaps
3. Condensers capable of Withstanding Power Line Voltage
4. Fuses capable of Breaking a Power Arc at the Line Voltage

5. Vacuum Spark Gaps
6. Static Spark Gaps
7. Fuses

(5–7: This equipment similar to that employed for Protecting Wire Telephone Systems Paralleling Power Lines.)

8. Mica Condensers capable of Withstanding a Potential of 10,000 Volts

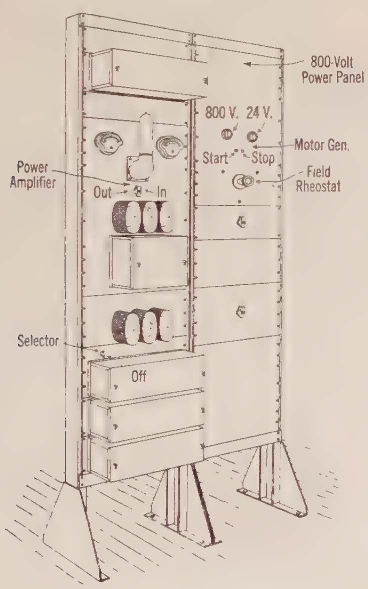


Fig. 7—Carrier Telephone Terminal Equipment

The carrier equipment, which has just been described, is suitable for power networks involving one or more transmission lines, extending for 100 miles or more from the load dispatcher's position. The exact length or extent of a transmission system over which this equipment will operate satisfactorily is, of course, difficult to predict and each installation must be considered separately.

The number of carrier terminals which may be operated on one power-transmission system is practically unlimited. It is easily conceivable that 10 or more carrier stations might be operated on a single line. This system would then compare with a commercial party-line telephone system, except that every station may call every other station without passing the call through a common point. In some cases, it may be desirable to pass the call through a common point. The change from one standard ringing key to another standard key accomplishes this result.

For power cables, the use of carrier telephony at frequencies of 100,000 cycles is not practical except in very short lengths of cable. However, lower frequencies may be employed for transmission on cables, although the coupling to the power conductor will be considerably complicated for lines of very high voltages.

To provide for those power systems, composed of several power lines operated by different companies but connected in parallel, the carrier frequencies may be located at various points in the band from 50 kilocycles to 150 kilocycles so as to avoid interferences between carrier systems.

## THE UNDERLIGHTED AMERICAN HOME

Notwithstanding the wonderful lighting progress visible on every hand, the Great American Home is still much underlighted. Just as has always been the case, general applications of good lighting lag behind the possibilities. Only *one third* of our homes are wired for electricity and these are less than half lighted. It is the duty of the lighting interests to raise the average to a conservative standard of convenience, comfort, and charm compatible with present possibilities. A leading illuminating engineer estimates that the average wired home needs 250 per cent more convenience outlets, 400 per cent more portable lamps, 250 per cent more wall brackets, 120 per cent more wattage of lamps, and 100 per cent more energy for lighting.

# CORRESPONDENCE

## ENGINEERING LITERATURE

*To the Editor:*

In an article on Engineering Literature in the February issue of the JOURNAL Mr. Donald McNicol says:—"As time goes on our store of literature increases. The task of the student who searches through the literature of a subject becomes increasingly prolonged. Should the files increase proportionately in the next fifty years, a situation might exist which would be serious." And further on: "From year to year the product of the will to write has increased. There is brought to the mill more grist than can be accommodated in periodicals conducted on an economical footing."

Mr. McNicol may be right in his prophecy with reference to the first statement, but the second statement obviously refers to a situation which is serious right now. The publication committee of the A. I. E. E. found it necessary to omit from the index of the 1922 TRANSACTIONS the titles of some half dozen out of the more than one hundred technical papers which had appeared in the JOURNAL during the year. When space amounting to a very small fraction of a page necessitates such fine distinction to be made between the wheat and the chaff of engineering literature, there is no doubt that the situation is serious, and that the time has arrived for condensing technical literature to a minimum of space requirement.

In a discussion on Industrial Research some years ago Professor Karapetoff remarked: "It is perhaps true that in Germany too much emphasis is laid upon mathematical relations, but in this country I would say that too much emphasis is laid on unrelated experiments. We have a prodigious maze of curves and data that can not be used for any purpose, because the results have not been put into mathematical form and generalized. It is a matter of efficiency and economy to try to perfect formulas and rational theories that would make a vast number of experiments unnecessary."

A vast amount of the technical literature of today appears to be descriptions and compilations of results of precisely such unrelated experiments as Professor Karapetoff refers to.

Another type of engineering literature, helping greatly to swell the total volume, are the papers and articles which the authors introduce by announcing that they have explained this or that phenomenon without the use of "mathematics," "higher mathematics," "seriously involved mathematics," etc. Indeed, in many cases the article's only claim to distinction is the absence of mathematics, the subject having previously been treated more thoroughly and concisely by the use of mathematics. Contributions of this type possess two outstanding characteristics:

1. Most of them do not contain quantitative analysis, and are thus of least value to those who must furnish specific answers to specific questions, and therefore are in greatest need of information on the subject under discussion.

2. Whether or not they contain some quantitative analysis, much more space is required to impart the information than if the language of concise mathematics had been used.

In view of the above, it appears that the logical method of condensing engineering literature is to encourage writers to express their ideas in mathematical form whenever possible. However, the policy of the A. I. E. E. seems of late to be tending rather in the opposite direction.

It is not intended to detract from the importance of the task, now being efficiently performed by commercial journals, of supplying a large circle of readers with interesting and descriptive articles of a semi-technical nature. However, the primary object of the publications of engineering societies is not to please the greatest number of readers, but to promote the application of science to industry. A paper that inspires a dozen, or even smaller number of individuals, to efforts along definite lines is much more likely to become a factor in promoting applied science than one which merely furnishes interesting reading to ten or twenty thousand persons.

K. L. HANSEN.

Milwaukee, Wis., February 25, 1924

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## ELECTRICAL MUSEUMS

*To the Editor:*

The progress in electrical engineering has been both rapid and extensive, so much so, that many are apt to overlook the admirable efforts of the past great engineers. With this in view, the subject of museums appears as a topic worthy of much discussion. There is little doubt that the evolution of a subject holds a certain interest for most people, yet they do not so readily grasp that therein lies the foundation of their and our progress, a foundation on which has been built the basic principles of our knowledge and that of the future generation. From this it is obvious that we must preserve those historic memories, in order that benefit may be derived from the "object lesson" which they undoubtedly provide.

May I offer an outline of the methods adopted in this country for the housing and preservation of such relics of science? Practically all of our cities have some form of museum or art gallery, and statistics show that these are being visited by thousands of people. Every endeavor has been made to provide a selection of subjects of a most varied nature, in order to meet the demand of the public in general. In meeting this demand, the engineer has in no way been forgotten and this generalization does not minimize the benefits derived. A certain specified area is allotted to each branch of science and is arranged in an admirable

fashion. The apparatus and devices exhibited are both historic and modern and many are of a workable nature. Methods of motive power are coupled to these machines and by merely pressing a push-button, they may be seen in actual motion. Many manufacturers have supplied exact minatures of their products, which show in detail every element of modern practise.

From my own knowledge, I am of the opinion that every type of mind has been catered to in the largest possible extent and from the numbers of students etc., who visit these places, a special and separate museum does not appear necessary. There seems a fair quantity of engineering relics available and many firms are quite prepared to provide samples of modern machinery, even though only in miniature. Therefore, if a museum is built of substantial size in the first instance, there will be ample accommodation for everything. I do not agree that a centrally located museum would be so beneficial, as was perhaps inferred. A concrete case is that of the British Empire Exhibition, now under construction in London and which is a modern marvel of science. However, there will be many engineers of the British Isles who will, perhaps, never see its walls. Therefore, for the benefit of the community, our associates, and the future generation, we must endeavor to share that which was shared with us.

Francis G. W. Tree,
Charge Engineer, Corporation Electricity Dept.
Glasgow, Scotland, February 26, 1924.

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*To the Editor:*

Referring to the Institute Journal for the month of February 1924 containing an Editorial article headed "Electrical Museums," permit the writer to call attention to an organization composed of the Association of Edison Illuminating Companies and the Edison Pioneers, which has been for some years devoting every energy within its power, to say nothing of large sums of money, in the effort to collect and provide adequate and proper permanent housing for existing historical electrical machines and devices; an occupation in which it is still actively engaged and expects to be engaged, as long as there remains anything of this nature possible and worthy of attainment.

As a matter of fact, practically all the electrical relics mentioned in the second paragraph of the article referred to are now in the hands of this Historical Collection, having been kindly placed there on loan by the A. I. E. E. Directors, the Association of Edison Illuminating Companies and others, and fill up a very creditable little museum in Room 616 of the Engineering Societies Building, including the Hammer collection of incandescent lamps, all of which may be seen at any time by arrangement with the Curator.

A still larger aggregation of historical electrical devices consisting principally of dynamo electric machines, both arc and incandescent, stationary and railway motors, arc and incandescent lamps, is to be found in the lower part of this City, in a thoroughly fireproof building, where it is constantly guarded by a trusted employee, awaiting the construction of a safe and permanent home in which to place it.

While thoroughly appreciating the importance of the interesting collection of early telegraph, telephone and electric power equipment now at the National Smithsonian Museum, the writer honestly believes no collection extant is comparable with the one above mentioned, embracing as it does the fields of telegraphy, telephony, phonography, electric light and power, both the actual apparatus as well as photographic and literary history appertaining.

It may also be of interest to know that in the gathering of all this early material, to save it from the junk pile or a possible destruction by fire, a large quantity of it has been generously donated or loaned by the eminent inventors themselves, contributed by many of our leading Universities and Manufacturers, Public Utility Corporations and private individuals, to all of whom we owe a debt of gratitude.

It may be remembered that much of this material was on exhibition in the Historical Section of the Electrical show at the Grand Central Palace in New York City during the month of October 1922, and the writer does not believe that anyone whose pleasure and profit it was to see it, met with disappointment. The Collection as then shown has been increased threefold, and it is our earnest intention to continue making additions thereto irrespective of the amount of labor involved, as long as there remains anything worthy and possible of attainment.

Our motives are purely altruistic, in no sense for the exaltation nor enrichment of any given individual, nor group of individuals, but an honest, earnest endeavor to preserve those things that show the development of the electrical science in this country, and the marvellous creations produced by America's men of genius, for the education of posterity.

F. A. Wardlaw, Curator.
New York, N. Y., March 11, 1924.

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## CONVERTED MOTOR SHIPS

The Seventh Annual Report of the U. S. Shipping Board shows the continuance of its policy to promote the sale of certain vessels at present equipped with inefficient propelling machinery at a price which will permit the installation of apparatus which will give low fuel costs and make the entire cost of the ship competitive. So far, ten ships, 64,911 deadweight tons cargo vessels and tankers have been sold for approximately $8.50 per ton, the contract for sale specifying that these vessels be converted into motor ships.

These converted motor ships will all be equipped with electrical equipment for operating winches, capstans, and other auxiliaries, thus adding materially to the economy of operation and advancing electrical development in the Merchant Marine.

# ILLUMINATION ITEMS

By the Lighting and Illumination Committee

## REQUIREMENTS FOR AN EFFECTIVE STOP SIGNAL

When the first really satisfactory automobile signal was brought out two or three years ago, and a new and thriving business created almost overnight, it did not mean that there had been no need for such signals in the past—that highways had suddenly become so cluttered with automobiles that signals found themselves removed from the luxury to the necessity class. Nor was it because motorists suddenly awakened to the fact that signals on their cars added appreciably to their appearance. It meant simply that rear-end collisions were dreaded by the motorist because of the alarming frequency with which they were occurring, particularly under crowded traffic conditions. Motorists were glad to welcome a device which would really minimize this danger, one which did not take their attention unduly from the work at hand just when it should be concentrated most on it, and at the same time was really effective and attracted attention from drivers behind in full sunlight as well as at night.


Fig. 1—Designed to Emit a Uniform Sparkle Over its Entire Face to All Points Within Which the Oncoming Car is Likely to be

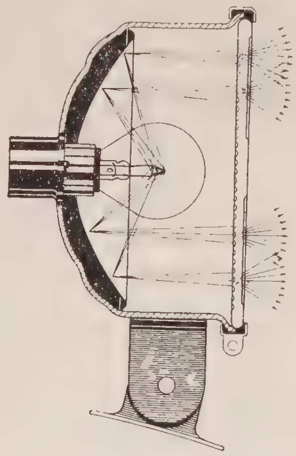

Fig. 2—By Opaquing Part of the Lens, Glare is Avoided Which Would Interfere with Vision of Approaching Drivers

The better signals which created the demand made a most favorable impression on the motorist and left no doubt in his mind as to the value of devices of this kind. That the flood of cheap and unreliable signals which were so much in evidence when the possibilities of the field were assured would arouse the distrust of the motorist and dull this favorable impression was of course to be expected. The fact that good signals continued to come into even more general use in spite of unsatisfactory experiences with inadequate designs, simply served to emphasize the need for protection from cars in the rear. Ten of the 27 car manufacturers each producing 10,000 or more cars per year, will equip their cars in 1924 with electrically lighted signals, whereas but three of this group were so equipped in 1923.

Needless to say, the motor car engineers are more particular than the average motorist in selecting equipments for installation, and far more competent to judge whether or not equipments will stand up in service and perform satisfactorily from the lighting standpoint. The prospective purchaser or dealer can profit by following their example and judging the value of a signal, with the following points in mind:

First—It should be sufficiently bright to compel attention, even in full sunlight. It will do so if equipped with 21-candle power lamps so placed as to locate the filament at the focal point of a highly polished silver-plated parabolic reflector and behind a cover glass so designed as to emit a brilliant and uniform sparkle over its entire face to all points within the effective angle within which the oncoming car is likely to be.

Second—It should not cause glare at night sufficient to interfere with the vision of drivers behind. The lens avoids such glare by opaquing part of the lens surface, thereby reducing the quantity of light flux directed to the approaching driver's eyes.

Third—The switching device should be convenient to the driver and be as nearly automatic in action as possible. It should definitely indicate the driver's intentions to change speed or direction or both before any actual change has taken place. The stop signal switch is ordinarily arranged to close automatically when the brake pedal is depressed.

Fourth—It should be provided with some form of reliable indicator so placed as to keep the driver definitely informed that his signal is working. A 2-candle power lamp mounted on the dash is usually used for this purpose. Its indication should be positive and definitely dependent upon the proper operation of the signal. It should of course use a standard lamp and be so connected in the circuit that its operation will not materially reduce the brilliancy of the signal itself.

Fifth—Since the signal is intended primarily to promote safety, it must be reliable and remain in operating condition with a minimum of attention. To insure reliability, switches should be provided with wiping rather than butt contacts, reasonably stiff spring fingers of adequate size, air insulation between fingers, and short action. Sockets should have solid current paths of low and unvarying resistance with springs so arranged that they cannot carry current. Wire should be of adequate size, preferably No. 14 B & S gage, stranded, and armored to withstand wear at points where it passes through holes in the frame.

Sixth—Standard lamps should be insisted upon in both signal and indicator to facilitate replacement. They should be interchangeable with those in other sockets on the car to provide for emergencies and reduce as far as possible the number of types of lamps to be carried in the driver's lamp kit.

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## Birmingham Convention Program

Arrangements for the Spring Convention at Birmingham as given in the March JOURNAL have been fully matured and indications point to a very interesting and instructive meeting. The general details of the meeting have already been published and need not be repeated here, but as some changes and rearrangement of the program have been made the final program of the technical sessions is given herewith:

**PROGRAM**

MONDAY, APRIL 7

MORNING

Technical—Committee Meetings and Registration.

2:00 P. M.—TECHNICAL SESSION—BALL ROOM

PAPERS:

*Hydroelectric Practises and Equipment in the South*. O. G. Thurlow, Alabama Power Company and J. A. Sirnit, Alabama Power Company.

*Hydroelectric Practises and Equipment on the Pacific Coast*, S. Barford, Consulting Engineer.

*Developments in Hydroelectric Equipment*, W. M. White, Allis-Chalmers Company.

*Acceptance Tests on Hydroelectric Stations*, F. H. Rogers, Wm. H. Cramp and Sons.

8:00 P. M.—INFORMAL RECEPTION AND DANCE AT BIRMINGHAM COUNTRY CLUB

TUESDAY, APRIL 8

9:30 A. M.—TECHNICAL SESSION—BALL ROOM

PAPERS:

*Lightning Arrester Tests*, W. F. Young, Duquesne Light Co.

*Lightning Arrester Experiences on the Pacific Coast*, E. R. Stauffacher, Southern California Edison Co.

*Lightning Arrester Design and Operation*, C. E. Bennett, Georgia Railway and Power Company.

*Economics of Lightning Arresters*, A. L. Atherton, Westinghouse Electric & Mfg. Co.

*Operating Experience with Relaying on the Duquesne System*, H. P. Sleeper, Duquesne Light Company.

2:00 P. M.—BALL ROOM

W. E. Mitchell, Chairman

PAPERS:

*Southern Power Developments*, Thos. W. Martin, President, Alabama Power Co. (Address).

*Financial Aspects of Hydroelectric Developments*, H. M. Addinsell, Harris Forbes and Company. (Address).

*New Type of High-Tension Interconnecting Network*, Percy H. Thomas, Consulting Engineer.

*Carrier Telephony on Power Lines*, N. H. Slaughter and W. V. Wolfe, both of Western Electric Company.

8:30 P. M.—JOHN HERBERT PHILLIPS HIGH SCHOOL AUDITORIUM

Thos. W. Martin, Chairman

Addresses

*National Water Power Development*, O. C. Merrill, Executive Secretary, Federal Power Commission.

*Best Ways of Using Water Power for the Benefit of the Public*, P. M. Downing. Vice-President, Pacific Gas and Electric Company.

*Public Relations in Water Power Development*, Preston Arkwright, President, Georgia Railway and Power Company.

WEDNESDAY, APRIL 9

9:30 A. M.—TECHNICAL SESSION—BALL ROOM

PAPERS:

*High-Tension Oil Circuit Breaker Tests*, H. J. Sholtz, Alabama Power Company.

*Alabama Power Company Breaker Tests*, R. W. McNeil, Westinghouse Elec. and Mfg. Co.

*Investigations of High-Voltage Breakers, Oil Breaker Tests*, A. J. D. Hilliard, General Electric Company.

*Oil Breakers from an Operator's Viewpoint*, J. V. Jenk, Wests Penn Power Company.

2:00 P. M.—TECHNICAL SESSION—BALL ROOM

PAPERS:

*New Synchronous Induction Motor*, Val A. Flynn, Consulting Engineer.

*65,000-Kv-a. Generators at Niagara Falls*, W. J. Foster and A. E. Glass, General Electric Company.

*Harmonics Due to Slot Openings*, C. A. M. Weber, Westinghouse Electric & Mfg. Co. and F. W. Lee of Johns Hopkins University.

*22,000-Kv-a. Transformers at Niagara Falls*, F. F. Brand, General Electric Company.

6:30 P. M.—OLD-FASHIONED SOUTHERN BARBECUE ON SHADES MOUNTAIN

Thursday, April 10

Special Train to Mitchell Dam and Lock 12.
Leave 7:00 A. M.—Return 7:00 P. M.

8:00 P. M.—Technical Session—Ball Room
Papers:

*Electrical Safety in Coal Mines*, L. C. Ilsley, U. S. Bureau of Mines.
*Automatic Sub-Stations for Mines*, C. E. Von Sothen, General Electric Company.
*Tests on Mine Hoist Control*, F. L. Stone and F. R. Grant, General Electric Company.
*Automatic Substations for Industrial Plants* Chester Lichtenberg, General Electric Company.

Friday, April 11

9:30 A. M.—Technical Session—Ball Room
Papers:

*New* 20-16 *Inch Strip Mill*. Noble Jones, West Leechburgh Steel Co., and G. P. Wilson, Westinghouse Electric & Mfg. Co.
*Maximum Demand Regulator for Electric Furnaces*, E. T. Moore, Halcombe Steel Company.
*Manufacture of Phosphoric Acid in Electric Furnaces*, Theodore Swann and F. V. Andrea, Federal Phosphorus Company.
*Effect of Impurities on Battery Electrolyte*, G. W. Vinal and F. W. Altrup, U. S. Bureau of Standards.

2:00 p. m.

Special visits to points of interest in the vicinity of Birmingham, for example, steel mills, textile mills, mines, foundries, substations and cement plants.

Note: At the close of the technical sessions special arrangements will be made to visit Muscle Shoals.

## Profitable and Enjoyable Program for Edgewater Beach Convention

A wide variety of technical features and an especially entertaining list of social sports events are on the program for the Annual Convention at Edgewater Beach, near Chicago, June 23-27. Also an entire day will be devoted to the conference of the Section delegates. Among the technical features there will be papers on distribution, transmission, cables, reactors, automatic substations, machinery, communication, electrophysics and street lighting. A special meeting will deal with the subject of standardization from several standpoints and on one morning the Technical Committees will report on the year's progress.

The entertainment features will be particularly enjoyable. A delightful boat trip on Lake Michigan has been arranged. There will also be an automobile trip through Chicago's excellent boulevards, in addition to inspection visits to an automatic telephone exchange, and automatic substation, the Western Electric Company's plant at Hawthorne, the Gary steel works, the Pullman Company and the Field Museum.

Golf, tennis and water sports will add to the pleasure of the meeting. Also teas and trips for the ladies are planned and there will be dancing at the hotel every afternoon and evening. On Thursday night a special fanciful entertainment will be staged.

## Pilgrimage of Pioneers to Pasadena Convention

A most delightful suggestion has come from some of the older members of the Institute in connection with the convention at Pasadena in October. This suggestion is that probably a large number of the pioneers of the Institute and other prominent engineers can make the trip to the Coast in a body and hold a reunion, it might be called, at the convention. It is proposed that the members from the East travel together in a special train or special cars, stopping briefly at interesting points.

The many engineers who went in a special train to San Francisco in 1915 will recall with pleasure the week of pleasant associations en route and the sights of unusual interest. There are three sights en route of world-wide interest, namely, the Grand Canyon of the Colorado, the Yosemite, and Great Salt Lake. There is nothing in the world quite comparable to these places.

In addition, it will be possible to view other well-known sights of interest, only secondary when compared to these three great ones. For example, at Colorado Springs there is Pike's Peak that may be visited by automobile, or the peculiar formations in the Garden of the Gods, the Cave of the Winds, Manitou, and Cheyenne Canyon. On the Denver and Rio Grande there is some fine mountain scenery exemplified in the Royal Gorge.

At Salt Lake City the point of greatest interest is the Mormon Tabernacle with its great organ music. As at Colorado Springs, an afternoon will be available at Salt Lake City. The time is sufficient to take a drive out beyond the University on the mountain side, overlooking the Great Basin. Saltair, the swimming and amusement resort, situated in Great Salt Lake, will be closed, but the Western Pacific Railway passes across one side of the lake. Several salt plants using natural evaporation are visible from the train.

Between Great Salt Lake and the Sierra Nevada Mountain, desert country must be crossed. That was an omnious experience for the early pioneers, but their difficulties are entirely in the imagination of a passenger inside a Pullman car. Train schedules are usually arranged so that most of the desert is crossed at night. Nevertheless, much of this waste country with its soft colors can be seen, and not infrequently with the landscape upside down in mysterious mirages.

After passing through the Sierra Nevada Mountains, the train winds through Feather River Canyon, made famous in the early days of placer gold mining in California.

At San Francisco, just across the Golden Gate, there is the peak of Mount Tamalpais, reached by railway. Mount Tamalpais overlooks San Francisco, San Francisco Bay and the Ocean.

Also as a part of this trip, by gravity railroad are the Muir Woods, where there are some fine examples of the Coast trees of California, the highest members of which are really taller than the big trees (Sequoia Gigante) of the Sierra Nevada Mountains. The Coast trees actually appear taller than the "big" trees, because they are of smaller diameter.

In San Francisco there are Golden Gate Park, the Cliff House, the Presidio, and Twin Peaks. From Twin Peaks there is an excellent view of treeless San Francisco. In the summertime when the sun is the strongest, the fogs, rolling in from the Ocean, supply shade in lieu of trees. In the fall, fogs are rare and the conditions around the Bay more favorable to sightseeing.

In and around Los Angeles the traveler can choose from many sights the most highly advertised in the world. For example, the movie cities and Catalina Island with its glass-bottom boats and fur seals. San Diego and Tia Jauna are best reached by automobile, with old Spanish missions and seashore resorts en route.

A special car can be obtained for twenty-five passengers and a special train for one hundred and twenty-five. Summer excursion rates will still be in force. The round-trip ticket from New York City, via Chicago, Colorado Springs, Salt Lake City, San Francisco, Los Angeles, Pasadena, Grand Canyon and Chicago, back to New York City is $147.44 (including the side trip to Grand Canyon and return).

From Pittsburgh and return via the same route it will be $122.17.

Tickets will bear final limit of time to reach the original starting point not later than midnight of October 31st.

The date of the Convention is so near the time limit on the

excursion ticket, that sight-seeing trips must precede the convention. The trips as laid out in a preliminary way will occupy about a month. Regulation of the summer rates requires purchase of tickets in September.

It is thought that a trip of this kind would offer a most acceptable opportunity for informal sociability and for renewing old acquaintanceships and making new ones.

It is requested that all who are interested in such an excursion kindly notify Headquarters of the Institute, in order that there will be some basis on which plans can be made.

## A. I. E. E. Annual Meeting

**PRESIDENT RYAN TO SPEAK**

The Annual Business Meeting of the Institute will be held in the Engineering Societies Building, New York, Friday evening, May 16, 1924. The results of the annual election of Institute officers will be announced and the report of the Board of Directors for the year ending April 30 will be presented.

Following the business meeting, the session will be continued under the auspices of the New York Section; and President Harris J. Ryan will address the members present on a subject to be announced later.

## Future Section Meetings

**Cleveland.**—April 24, 1924. Subject: "Economic Phases of Proper Illumination." Speaker to be announced later.

**New York.**—April 16, 1924. Subject: "The Telephone Systems of Greater New York." Paper by Mr. G. M. McRae, New York Telephone Company, covering the telephone problems of today, together with a description of the plant and methods needed to provide the service desired in the Metropolitan area. Plans for the estimated future growth will be touched upon. This meeting will also be the annual business meeting of the Section required by the By-laws, at which the results of the election of officers for 1924-25 will be announced.

**Philadelphia.**—April 14, 1924. Subject: "Railroad Electrification—Its Present Development and Future." Speaker: Mr. J. Van Buren Duer, of the Pennsylvania System.

**Pittsfield.**—April 10, 1924. Subject: "Machine Guns and Automatic Rifles." Speaker: Major Earl McFarland, Ordinance Dept., U. S. Army.

May 1, 1924. Subject: "The Electrical Transmission and Reproduction of Speech." Speaker: Mr. W. H. Martin, of the American Telephone and Telegraph Company.

**Vancouver.**—May 2, 1924. Subject: "British Columbia Electric Railway Co. Developments." Speaker: Mr. J. I. Newell.

## The American Society of Mechanical Engineers

The Spring Meeting of the A. S. M. E. will be held in Cleveland, May 26-29, 1924. Some of the subjects to be discussed are Power Problems in the Steel Industry, Interchangeable Manufacture, Windmill and Fan Design, and Materials Handling in Industry. Joint sessions will be held with both the American Society for Testing Materials and the American Society of Refrigerating Engineers.

## A. S. C. E. Spring Meeting, Atlanta, Ga.

The Spring Meeting of the American Society of Civil Engineers, to be held in Atlanta, Ga. April 9-12, promises to be a most interesting and instructive one.

The economics and the operation of hydroelectric power developments, the influence of railroads on industrial development, highway and water-supply problems, all of which will be discussed, offer a wide and important field in which the country at large is interested.

In addition to the technical program, the local engineers of Atlanta have arranged interesting social events and sight-seeing excursions. Atlanta has many points of scenic and historic importance, probably the best known and most widely discussed being the mammoth Confederate Memorial now being sculptured on Stone Mountain.

## A. E. S. Spring Meeting—April 24-26

The spring meeting of the American Electrochemical Society will be held in Philadelphia, April 24, 25 and 26. The technical meeting will be devoted to a symposium on "Organic Electrochemistry." Dr. C. J. Thatcher, of New York City, acting as chairman; and to a symposium on the subject: "Recent Progress in Electrodeposition" when Mr. S. Skowronski, Research Chemist of the Raritan Copper Co., will be chairman.

There will also be a Round Table discussion on "Electric Furnace Refractories." In addition, there will be papers on this subject and two lectures delivered by Dr. D. J. Barnett and Mr. John Mills.

Many interesting trips and entertainments have been planned by the local committee.

## Meeting of the American Physical Society

The regular meeting of the American Physical Society will be held in Washington at the Bureau of Standards, April 25-26, 1924. The first session will begin at 10 o'clock Friday morning and in the evening then will be an informal dinner, commemorating the twenty-first anniversary of the founding of the Society.

## A. I. E. E. Directors Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Friday, March 14, 1924.

There were present: Past Presidents Frank B. Jewett and William McClellan, New York; Vice-Presidents W. I. Slichter, New York, R. F. Schuchardt, Chicago, G. Faccioli, Pittsfield, Mass., J. E. MacDonald, Los Angeles, William F. James, Philadelphia; Managers Harold B. Smith, Worcester, Mass., E. B. Craft, H. P. Charlesworth, New York, H. M. Hobart, Schenectady, N. Y., Ernest Lunn, Chicago, G. L. Knight, Brooklyn, N. Y., R. B. Williamson, Milwaukee, A. G. Pierce, W. M. McConahey, Pittsburgh, Harlan A. Pratt, Hoboken, N. J., W. K. Vanderpoel, Newark, N. J.; Treasurer G. A. Hamilton, Elizabeth, N. J.; Secretary F. L. Hutchinson, New York.

A report of a meeting of the Board of Examiners held March 3 was presented, and the actions taken at that meeting approved. Upon the recommendation of the Board of Examiners the following action was taken upon pending applications: 243 Students were ordered enrolled; 295 applicants were elected to the grade of Associate; 11 applicants were elected to the grade of Member; one applicant was elected to the grade of Fellow; 8 applicants were transferred to the grade of Member.

Approval by the Finance Committee of monthly bills amounting to $18,387.03 was ratified.

The Secretary reported that the Meetings and Papers Committee has been very active and that unusual progress had been made in connection with the programs for the three remaining conventions of 1924, namely, the Spring Convention, Birmingham, Ala., April 7-11; Annual Convention, Chicago, June 23-27; and the Pacific Coast Convention, Pasadena, Calif., October 13-18.

The Secretary called attention to the announcements published in the March Journal regarding the World Power Conference to be held in London in July, and the meetings of various British engineering organizations following the World Power Conference, also regarding the meeting of the Czechoslovakian Electrical Association two or three weeks later, in Prague. He requested that he be advised of the names of any

members of the Institute who expect to attend the World Power Conference, in order that he might transmit their names to the American Committee on Participation for inclusion in the list of members of, or delegates to, the Conference.

Attention was also called to the communication that has been received from the British Institution of Electrical Engineers, as published in the March JOURNAL, inviting a delegation of about forty members of the A. I. E. E. and their ladies to attend various meetings and other functions in London, in July; and a letter from the Secretary of the British Institution of Civil Engineers was presented, requesting a list of names and addresses of A. I. E. E. members and their ladies who expect to be in London next summer, for use in connection with the issuing of invitations to a Joint Engineering Conversazione to be held at the headquarters of the Institution of Civil Engineers on the evening of July 15, upon the invitation of the Presidents and the present and former members of the Councils of the Institution of Civil Engineers, the Institution of Mechanical Engineers, and the Institution of Electrical Engineers.

In view of the importance of the World Power Conference and the meetings of other engineering organizations immediately following—all of which will comprise a remarkable gathering of engineers from all over the world, and for the purpose of fostering relations with the European engineering organizations, it was considered desirable for the Institute to send its President and its Secretary to these meetings; and it was voted that it is the sense of this Board that the President and the Secretary of the Institute should attend the World Power Conference and other European meetings.

A communication from the Secretary of the Kelvin Centenary Committee was presented, inviting the Institute to name a member of a Committee of Honour, to consist of representatives of scientific and technical bodies, in connection with the Kelvin Centenary Celebrations in London, July 10-11. The appointment of a member of this committee was delegated to the Executive Committee.

Upon the recommendation of the Committee on Student Branches, the Board authorized the organization of a Student Branch of the Institute at Rhode Island State College, Kingston, R. I.

A report of the Board's Committee on Standards Committee Procedure was presented, and adopted, as outlined elsewhere in this issue.

The report of the Committee of Tellers on the nomination ballots that were received for the offices to be filled at the coming annual election of the Institute, was presented and the Board selected "Directors' Nominees" as indicated elsewhere in this issue.

Upon the request of the Secretary, the time for the receipt of papers in competition for the 1923 First-Paper Prize was extended to May 1, 1924.

Announcement was made of the reappointment by President Ryan of Professor Charles F. Scott as a representative of the Institute on the Commission of Washington Award, for a term of two years commencing June 1, 1924.

Reference to other matters discussed may be found in this and future issues of the JOURNAL under suitable headings.

## A. I. E. E. Annual Election

At the meeting of the Board of Directors of the Institute held in New York March 14, the report of the Committee of Tellers, giving the result of its canvass of the nomination ballots received for the offices to be filled at the coming annual election, was presented.

This report included the names of all candidates eligible for election, the names of those who received less than three per cent of the total nomination vote having been eliminated, in accordance with the requirements of the constitution.

There were two candidates for the presidency, namely, Charles E. Skinner, of Pittsburgh, Pa., who received 2448 nomination votes, and Farley Osgood, of Newark, N. J., who received 2238 votes. The Board decided not to select a "Directors' Nominee" for the office of president; and the names of both eligible candidates appear upon the final ballot.

The Board then selected the following list of "Directors' Nominees" for the other offices to be filled:

| | |
|---|---|
| For Vice-Presidents: | District No. 1 (North Eastern) |
| | Harold B. Smith, Worcester, Mass. |
| | District No. 3 (New York City) |
| | L. F. Morehouse, New York, N. Y. |
| | District No. 5 (Great Lakes) |
| | Edward Bennett, Madison, Wis. |
| | District No. 7 (South West) |
| | H. W. Eales, St. Louis, Mo. |
| | District No. 9 (North West) |
| | John Harisberger, Seattle, Wash. |
| For Managers: | John B. Whitehead, Baltimore, Md. |
| | E. B. Merriam, Schenectady, N. Y. |
| | J. M. Bryant, Austin, Texas |
| For Treasurer: | George A. Hamilton, Elizabeth, N. J. |

The election ballots were mailed to the entire membership prior to April 1, in accordance with the constitution.

The report of the Committee of Tellers follows:

### REPORT OF COMMITTEE OF TELLERS ON NOMINATION BALLOTS

March 11, 1924

*To the Board of Directors,*
*American Institute of Electrical Engineers*

Gentlemen:

This Committee has counted and canvassed, in accordance with Article VI of the Constitution, the nomination ballots received for officers of the Institute for 1924-1925. The result is as follows:

| | | |
|---|---|---|
| Total number of envelopes said to contain ballots received from the Secretary | | 4931 |
| Rejected on account of bearing no identifying name on outer envelope | 79 | |
| Rejected on account of having reached Secretary's office after February 29 | 71 | |
| Envelopes received containing no ballots | 4 | |
| Leaving as valid ballots | | 4777 |

These valid ballots were counted and the result is shown below:

FOR PRESIDENT

| | |
|---|---|
| Charles E. Skinner | 2448 |
| Farley Osgood | 2238 |
| Scattering and blank | 91 |
| Total | 4777 |

(The scattering vote was divided among 11 candidates, each of whom received less than 3 per cent of the total vote. Detailed distribution of these votes is shown on the original tally sheets filed in the Institute offices).

FOR VICE-PRESIDENTS

| District | | |
|---|---|---|
| No. 1. North Eastern | | |
| | Harold B. Smith | 3879 |
| | Scattering and blank | 898 |
| No. 3. New York City | | |
| | L. F. Morehouse | 2667 |
| | Philip Torchio | 1750 |
| | Scattering and blank | 360 |
| No. 5. Great Lakes | | |
| | Edward Bennett | 2044 |
| | Chester D. Hall | 1788 |
| | Scattering and blank | 945 |

No. 7. South West

| | |
|---|---|
| H. W. Eales | 2015 |
| George C. Shaad | 1746 |
| Scattering and blank | 1016 |

No. 9. North West

| | |
|---|---|
| John Harisberger | 3602 |
| Scattering and blank | 1175 |

(The scattering vote was divided among 23 candidates, each of whom received less than 3 per cent of the total vote. Detailed distribution of these votes is shown on the original tally sheets filed in the Institute offices).

FOR MANAGERS

| | |
|---|---|
| John B. Whitehead | 2175 |
| E. B. Merriam | 2073 |
| H. A. Kiddie | 1883 |
| J. M. Bryant | 1665 |
| Edward L. Moreland | 1630 |
| Julian C. Smith | 1576 |
| Ross B. Mateer | 1170 |
| Scattering and blank | 2159 |

(The scattering vote was divided among 28 candidates, each of whom received less than 3 per cent of the total vote. Detailed distribution of these votes is shown on the original tally sheets filed in the Institute offices).

FOR TREASURER

| | |
|---|---|
| George A. Hamilton | 3677 |
| Scattering and blank | 1100 |
| Total | 4777 |

(The scattering vote was divided among 13 candidates, each of whom received less than 3 per cent of the total vote. Detailed distribution of these votes is shown on the original tally sheets filed in the Institute offices).

Respectfully submitted,
J. B. Bassett, *Chairman*
James F. Kelly
R. R. Kime
Irving W. Green
B. Tikhonovitch
*Committee of Tellers*

## A. I. E. E. Year Book

The A. I. E. E. 1924 Year Book is available to members without charge, upon application to the secretary, 33 West 39th Street, New York, N. Y.

The book contains an alphabetical and geographical catalog of the membership, revised to January 1, 1924; also the constitution, by-laws, lists of officers and committees, and much additional information relating to the activities of the Institute.

## U. S. National Committee of I. E. C.

**REORGANIZATION MEETING**

At the meeting of the Council of the International Electrotechnical Commission, held in Paris December 3rd last, Dr. C. O. Mailloux, who had been President of the Commission since 1919, retired, and was succeeded by Mr. Guido Semenza of Milan. Subsequently, in view of his distinguished services with the Commission, Dr. Mailloux was elected Honorary President of the Commission. An election was held also of the other general officers of the Commission. This Commission is represented in this country by the United States National Committee of the International Electrotechnical Commission, of which Dr. Mailloux was President also.

The Constitution of the U. S. National Committee provides that the terms of all appointed members of the Committee shall expire whenever the International Commission holds a general election of officers. Therefore the organizations represented on the U. S. National Committee were requested to make new nominations for membership on this Committee. These organizations responded, and as a result the Committee as now constituted is composed as follows:

**U. S. NATIONAL COMMITTEE—I. E. C.**

**Representing American Institute of Electrical Engineers**

| | |
|---|---|
| C. A. Adams | F. V. Magalhaes |
| J. J. Carty | A. S. McAllister |
| L. W. Chubb | A. H. Moore |
| W. A. Del Mar | F. D. Newbury |
| Gano Dunn | L. T. Robinson |
| H. W. Fisher | D. W. Roper |
| H. M. Hobart | Charles F. Scott |
| D. C. Jackson | C. E. Skinner |
| A. E. Kennelly | Elihu Thomson |
| B. G. Lamme | R. B. Williamson |
| C. O. Mailloux | C. H. Sharp |

*Ex-Officio*

| | |
|---|---|
| G. L. Knight | H. S. Osborne |
| H. J. Ryan | |

**Representing Electrical Manufacturers Council**

| Nominated by Associated Manufacturers of Electrical Supplies | Nominated by Electric Power Club |
|---|---|
| C. A. Bates | James Burke |
| LeRoy Clark | C. L. Collens |
| R. W. E. Moore | A. L. Doremus |
| H. R. Sargent | A. E. Waller |

**Representing American Society for Testing Materials**

C. L. Warwick

**Representing National Electric Light Association**

L. L. Elden   Geo. H. Harries
S. G. Rhodes

**Representing American Engineering Standards Committee**

P. G. Agnew

**Representing Department of Commerce**

R. A. Lundquist

**Representing Bureau of Standards**

Dr. G. K. Burgess

**Representing Navy Department**

Lieut. Com. C. S. Gillette, Bureau of Engineering

**Representing War Department**

Major Gen. C. McK. Saltzman, Chief Signal Officer

The Committee so organized held its first meeting on March 12th and completed its organization by the election of officers and of its Executive Council. Dr. Mailloux, who had served the Committee with the utmost fidelity and success for a long period of years, since the retirement of the late Prof. F. B. Crocker from that position, signified his desire of being relieved of the burden of the presidency, and the Committee, with great regret, acceded to his wish. Thereupon Dr. C. H. Sharp was elected President of the Committee, and immediately thereafter Dr. C. O. Mailloux was, by unanimous resolution, elected Honorary President of the Committee and ex-officio member of the Council and of all subcommittees. In making this appointment the Committee wished, by following the precedent set by the International Electrotechnical Commission, to express its recognition of the unselfish, untiring and effective services of Dr. Mailloux which have been devoted no less to the United States National Committee than to the international body. The Committee furthermore hopes in this way to retain the advantage of Dr. Mailloux' counsel and advice which, seasoned by long contact with the whole movement from its inception in 1906, the Committee feels to be invaluable.

Prof. D. C. Jackson and Mr. James Burke were re-elected Vice-Presidents; Mr. S. G. Rhodes was elected Secretary and Treasurer. As members of the Executive Council there were appointed from the American Institute of Electrical Engineers' group—Messrs. L. T. Robinson, D. C. Jackson and C. E. Skinner; from the other group of appointed members—James Burke, A. L. Doremus and C. A. Bates.

The Institute of Radio Engineers was invited to become affiliated with the U. S. National Committee and appoint delegates to that Committee.

It was announced that meetings would be held in London on July 15th, 16th and 17th of the Advisory Committees on Rating of Electrical Machinery, on Nomenclature and on Graphical Symbols of the I. E. C., and the Executive Council was authorized to nominate delegates to these meetings.

## Graduate School, Yale University

**FELLOWSHIP IN TRANSPORTATION**

A Strathcona Memorial Fellowship in Transportation, of One Thousand Dollars, is offered annually for advanced work in Transportation, with special reference to the construction, equipment and operation of railroads, the problems connected with the efficient transportation of passengers and freight and the financial and legislative questions involved. The holder of the Fellowship must be a man who has obtained his first degree from an institution of high standing. In making the award, preference is given in accordance with the will of Lord Strathcona to such persons or to sons of such persons as have been, for at least two years, connected in some manner with the railways of the Northwest.

Applications for this Fellowship should be addressed to the Dean of the Graduate School of Yale University, New Haven, Conn., before May 1, on blanks which may be obtained from the Dean, and should be accompanied by

1. A statement of the applicant's education and practical experience.
2. A statement of the particular field of interest to the applicant and his reasons and purposes for desiring the Fellowship.
3. Letters of recommendation.
4. Reprints of articles or publications by the applicant.

## Ambrose Swasey to Receive the John Fritz Medal

The program for the presentation of the John Fritz Gold Medal to Ambrose Swasey at 8:30 p .m., Wednesday, April 23rd, in the Auditorium of the Engineering Societies Building, New York, N. Y., will be most interesting.

Chairman Charles F. Rand of the Board of Award will preside and addresses will be made by Gen. William Crozier, formerly Chief of Ordnance, U. S. Army, and Dr. William W. Campbell, President of the University of California.

The medalist will be presented by Dr. John R. Freeman, member of the Board of Award, and the medal will be conferred by Chairman Rand. There will be a response by Mr. Swasey.

## Addresses at the A. I. E. E. Railroad Meeting in Philadelphia

A number of requests for copies of the addresses given at the evening railroad session of the A. I. E. E. Midwinter Convention has been received, and as no space in the JOURNAL is available for printing these addresses, a limited number of mimeograph copies has been prepared for distribution among those especially interested in this subject. These copies may be obtained on request to Institute Headquarters.

## Standards of A. I. E. E.

The formulation and publication of Standards has constituted one of the most important activities of the American Institute of Electrical Engineers during the past quarter of a century.

The present Standards of the Institute are therefore the result of more than twenty-five years' work conducted by members actively engaged in the design, manufacture, operation and specifying of electrical apparatus. These men have freely contributed of their time and knowledge and have conducted much experimental work for the purpose. The Standards are generally accorded recognition as the best American practise and experience in the fields covered.

During the past two years there has been much discussion in regard to the future activities of the Institute in connection with the formulation and publication of Standards, and various conferences have been held with representatives of other organizations in the field of electrical engineering and the electrical industry in general in an endeavor to find the best method of coordinating such work with the view to final publication of electrical engineering standards in accordance with the plan of procedure adopted by the American Engineering Standards Committee, which is the agency set up by a large number of organizations, including the A. I. E. E., for the coordination of the standardization work of the various member organizations.

On December 14, 1923, the Board of Directors adopted the following resolution:

RESOLVED: That the Board expresses the opinion that the Standards Committee should take no action that will interfere with the continued construction and publication of A. I. E. E. Standards, as its principal function made from the standpoint wholly of the American professional electrical engineer; and that while doing this they should cooperate to the greatest extent possible with all other bodies interested in Standards. This to the end that the integrity of the standards developed by the Standards Committee within its specific scope and adopted by the Institute, will be maintained.

At the same meeting, it was

VOTED: That a committee of this Board be appointed to confer with the Standards Committee for the purpose of determining the methods of procedure that will be acceptable to both the committee and the Board of Directors.

In accordance with this action, a committee of the Board was appointed, consisting of Messrs. A. G. Pierce, Chairman, H. M. Hobart, William McClellan, W. I. Slichter and W. K. Vanderpoel. This committee conferred with a subcommittee of the Standards Committee, consisting of Messrs. F. D. Newbury, Chairman, D. C. Jackson, Harold Pender and L. T. Robinson, and the latter committee in turn consulted with various other organizations.

As a result of these meetings and of a very careful study of the whole situation at the present time, the Board's committee presented a report at the meeting of the Directors held March 14, 1924, recommending that the policy outlined in the above resolution of December 14 be reaffirmed, and that the work of revision of the present Institute Standards be actively carried on to completion. This report said in part:

"Throughout an extended period the American Institute of Electrical Engineers has engaged actively in the development of standards appertaining to, or applicable in, electrical engineering and in the allied arts and sciences.

"These standards have been accepted generally as authoritative, and have been found to meet (within their scope) the needs of the industry.

"Your committee considers that the very considerable measure of success which has attended this work is in great part due to the fact that the work has been done from the standpoint of the professional electrical engineer and under the auspices of an impartial professional society of standing.

"With regard to the subject of Scope, there can be no hard and fast definition given. We recommend that the Standards Committee take as a criterion the general character and extent of the 1922 edition of the Institute Standards and that special attention be directed to the note entitled, 'Purpose of the Standards of the A. I. E. E.' on page ii of that publication."

The statement referred to in the last paragraph reads as follows:

In framing these standards the chief purpose has been to define the terms and conditions which characterize the rating and behavior of electrical apparatus, with special reference to the conditions of acceptance tests.

It has not been the purpose of the standards to standardize the dimensions or details of construction of any apparatus, lest the progress of design should be hampered.

"It is recognized that the scope of the Institute's Standards covers only a portion of the required field, but we are satisfied that it is the portion, from the standpoint of the interests of the industry, that can be covered most effectively 'from the standpoint of the professional electrical engineer.'

"The Institute's Standards Committee should, and will, continue to maintain those close and hearty relations with other organizations which have proved so effective in the past.

"An important agency in promoting the coordination of the work of various organizations in the standardizing field in the A. E. S. C., in the establishment of which the A. I. E. E. played the initiating part and in the support of which it continues.

"The pending revision of the A. I. E. E. Standards is being subdivided into Standards relating to component subjects and it is anticipated that each one of these component standards after its adoption as A. I. E. E. Standards, will in due course become an American Standard, either by itself or merged with the Standards submitted by other organizations, by the procedure established by the A. E. S. C. for the purpose.

"Your committee, however, cannot too strongly present the importance of first directing the efforts of the Standards Committee to the completion of its revisions with a view to their early adoption as A. I. E. E. Standards.

"We recommend

1. That this report be adopted with a spirit of action rather than one of sentiment.

2. That it be understood that the policy thus reaffirmed must be sustained through the changes of personnel in future Boards and Committees to permit a constructive forward work of this character necessarily to go on without the interruption caused by uncertainty as to policy.

3. That this settled policy can be sustained only by belief generally in the plan, character, scope, thoroughness and speed with which this work of our Institute is produced.

4. That to insure the foregoing, earnest attention to it must be given, individually by the members of the Board both by way of encouragement to the Standards Committee and by interesting others in Institute circles generally in this work.

5. That it be recognized that the task imposed both as to scope, speed of production and cooperation with other associations or groups similarly employed may require greater effort than can be commanded by voluntary contribution, and in view of this that immediate consideration be given to employment of the services of a technical assistant on the staff of the Secretary to give active attention under direction of the Standards Committee to the prosecution of the work.

6. That the Standards Committee report to the Board such changes in By-laws 11a and 11b as will remove any technical delay in consideration of standards as they become ready for release."

The Board of Directors voted to approve the report referred to above and to adopt all the recommendations referred to therein.

## Activities of the Lynn Section

The Lynn Section of the A. I. E. E. has shown itself to be a live and growing organization especially during the last three or four years. Increasing membership has permitted it to extend its activities in several lines to meet the varying interests of its membership. The Bi-Weekly addresses by speakers of high calibre continue to be the chief activity of the section. It has added to this a committee which provides a trip each month to some nearby Industrial or Educational Institution. These trips have met the general approval of the membership and are very well supported. Five or six trips constitute the program for the season, and include the Massachusetts Institute of Technology with its laboratories, the Charlestown Navy Yard, the Hood Rubber Company with its tire industry and the Army Fortifications of Boston Harbor.

A later development which will undoubtedly prove to be a very valuable addition to the activities of the Section is that of the local conventions.

It is believed that the preparation and presentation of papers by local members represents a very real opportunity for the development of the individual and for those who take an intelligent part in the discussion. Those who do not take part in the discussion will benefit by the increased store of knowledge of the subject covered and from observation of the methods used by the authors in presenting their ideas. The object of these local conventions is to enable the members to secure greater benefit from their connection with the Institute by personal participation in its activities. This sentiment has gained the favor of the national body and by cooperative efforts a plan has resulted which will embody these ideas.

The plan calls for three technical sessions during the current season, at which original papers, developed by members of the local section, will be read for the approval of the members and will be followed by a general discussion of the technical points.

Subjects which hitherto have had very limited discussion and publicity will be brought forward to receive the full benefit of general discussion by the members. An opportunity will be provided to present subjects before an assembly more or less familiar to them and give the speakers training which will be valuable to them when presenting papers before larger assemblages.

The national body will be benefited by having a much larger number of investigators and scientists from which to draw for their various activities.

The national body has offered a prize of $100 for the best original paper to be presented before a local section during the season and a $25 prize for the best paper presented in any one of the several districts. The Lynn section has added a $15 prize for the best paper presented by members in any of the three technical sessions. The rule for eligibility is that the author shall not have presented a paper at any meeting of the national body.

The first meeting of the series was held Jan. 23, 1924. Two papers were read and discussed. The first paper by Mr. George R. Prout dealt with the recent development in induction motors. The title of his paper was "Deep Bar Effect in Induction Motors" The second paper was read by Mr. William A. Tripp. His subject was "Power Losses in Cable and Dielectrics."

As a departure from the regular activities of the Institute, this first Convention was deemed an experiment. It was found, however, that as an experiment, it was very successful, and from the interest shown gives promise to be the forerunner of a permanent activity.

# ENGINEERING FOUNDATION

### PAINT INVESTIGATION

Federal aid for a non-commercial investigation into the nature and use of paint and varnish is urged in a statement by a special committee of the Engineering Foundation, the national research instrumentality of the four great engineering groups of civil, mining, mechanical, and electrical engineers.

The question of paint, it was pointed out, is intimately bound up with the problem of housing. Congress, it was said, should place at the disposal of the Forest Products Laboratory about $45,000, which is estimated to be equal to one one-hundredth of one per cent of the value of paint used annually in this country. Architecture being closely associated with the situation which the Committee describes, the American Institute of Architects was cited as one of numerous representative organizations which are sponsoring the promotion of research in this field.

The Bureau of Standards, of the Department of Commerce,

is also working on the problem, giving attention especially to the characters of paints and varnishes. This undertaking has the approval of the Engineering Foundation, National Research Council, the American Institute of Architects, the American Farm Bureau Federation, the American Railway Association and numerous organizations interested in the use of wood for industrial purposes. These matters affect everyone.

## Electrical Symbols for Building Plans

Final action in the Sectional Committee to which these symbols had been referred was unanimously voted upon and letters, signifying the approval by the three sponsors, were received from the American Institute of Architects, American Institute of Electrical Engineers, and the Association of Electragists, International. The Special Committee on approval of the standard reported in part as follows:

"We, therefore, recommend that the symbols for wiring plans for buildings be approved as now proposed by the Sectional Committee and the preparation of standard symbols for wiring plans for marine installations be transferred to the Sectional Committee for Electrical Installations on Shipboard, under Mr. Hibbard as Chairman, and that the latter be instructed to prepare such symbols."

At its meeting on February 14, the Executive Committee approved the report of the Special Committee and ordered the approval of the symbols as a tentative American standard.

## Addresses Wanted

A list of names of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify the Institute headquarters promptly of any change in mailing or business address, thus relieving the member of needless anoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

1.—John P. Byron, c/o Waldorf Hotel, Seattle, Wash.
2.—D. S. Dewire, 39 6th Ave., La Grange, Ill.
3.—F. S. Douglass, Schweitzer & Conrad Inc., 4435 Ravenswood Ave., Chicago, Ill.
4.—R. C. Elliott, Box 502, Wenatchee, Wash.
5.—W. J. Gibbons, Toko St., Rotorua, N. Z.
6.—Frank W. Griffin, Sorgel Electric Co., 138 W. Water St., Milwaukee, Wis.
7.—Jerome S. Haas, 2011 Atlantic Ave., Atlantic City, N. J.
8.—Henry C. Schnake, 21 E. 40th St., New York, N. Y.
9.—W. J. Timmins, 1219 11th St., Des Moines, Iowa.

# Engineering Societies Library

*The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.*

*In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.*

*The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.*

*The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.*

### BOOK NOTICES (Feb. 1-29, 1924)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

ALBUM DE PLANS DE POSE POUR L'INSTALLATION DE LA FORCE PAR L'ELECTRICITE.

By H. De Graffigny. Paris, Gauthier-Villars et Cie., 1922. 143 pp., diagrs., 9 x 6 in., paper. 7 fr.

A collection of thirty-five plates showing wiring diagrams for industrial uses of electricity. These vary in difficulty from the simple connection of a direct-current generator and motor to the connections for an automatic substation for a railroad or lighting system. A brief description accompanies each plate.

ALTERNATING-CURRENT ARMATURE WINDING.

By Terrell Croft. N. Y., McGraw-Hill Book Co., 1924. 352 pp., illus., diagrs., tables, 8 x 6 in., cloth. $3.00.

This is a practical book for those interested in winding or rewinding alternating-current stators. It does not discuss design nor contain any advanced mathematics.

Starting with the necessary definitions and classification of machinery, directions are given for rewinding machines for their original conditions, for reconnecting windings to suit changed conditions, and for unusual connections. A section on testing windings and locating faults is included. The final section consists of 165 diagrams of standard connections for single-phase, two-phase and three-phase windings.

COLLOID SYMPOSIUM MONOGRAPH; Papers and Discussions presented at the First National Symposium on Colloid Chemistry, Univ. of Wisconsin, June, 1923.

By J. Howard Matthews, editor. Madison, Wis., Dept. of Chemistry, Univ. of Wis., 1923. 419 pp., illus., diagrs., 9 x 6 in., paper. $2.75.

The National Symposium on Colloid Chemistry was organized for the purpose of bringing together those interested in the subject, for discussion of the many problems which confront the worker in this rapidly changing field. Twenty-five papers by prominent investigators are here reproduced, with the discussions. A wide range of topics is covered; among them, the colloidal state in metals and alloys, the colloidal properties of rubber and compound ingredients, and the chemical reactions of colloidal clay.

ECONOMICS OF MOTOR TRANSPORTATION.

By George W. Grupp. N. Y., D. Appleton & Co., 1923. 414 pp., illus., 9 x 6 in., cloth. $4.00.

This book attempts to cover the entire field in as much detail as is possible within the limits of a single volume, with due regard to the needs of students of transportation, manufacturers of motor vehicles, and owners or prospective owners of trucks. Attention is concentrated on the principles involved in road transport and on the methods of applying these principles successfully. Among the subjects discussed are the replacement of horse wagons, selection of trucks, track operation, loading, cost accounting and omnibus transportation.

Galvanomagnetic and Thermomagnetic Effects.

By L. L. Campbell. N. Y., Longmans, Green & Co., 1923. (Monographs on physics). 311 pp., diagrs., 9 x 6 in., cloth. $5.25.

This monograph reviews concisely, yet in detail, the historical, experimental and theoretical accounts of that family of galvanomagnetic and electromagnetic phenomena that are the lineal offspring of the Hall effect. Includes, in addition to the Hall effect, those known as the Ettingshausen, Nernst, and Righi-Leduc effects. An extensive bibliography is included.

Die Kraftstellwerke der Eisenbahnen, vol. 1; Die Elektrischen Stellwerke.

By S. Scheibner. Berlin & Leipzig, Walter de Gruyter & Co., 1923. 122 pp., illus., diagrs., 6 x 4 in., boards. $.30.

A concise outline of three German systems of electric interlocking and signaling; those of Siemens & Halske, of Max Jüdel & Co. and of the Allgemeine Elektrizitäts Gesellschaft.

Life of Francis Amasa Walker.

By James Phinney Munroe. N. Y., Henry Holt & Company, 1923. 449 pp., port., 9 x 6 in., cloth. $4.00.

General Walker has many claims to fame as a soldier, an economist and a public official, but to engineers he is best known for his work at the Massachusetts Institute of Technology, of which he was President from 1881 to 1897. Mr. Munroe's biography, published twenty-five years after General Walker's death, gives a full account of his busy life and a careful estimate of his contributions to the reforms in government, in education and in social administration for which he labored.

Preparation of Reports; Engineering, Scientific, Administrative.

By Ray Palmer Baker. N. Y., Ronald Press Co., 1924. 468 pp., illus., diagrs., 8 x 5 in., cloth. $3.50.

Dr. Baker's work, while intended primarily for students, contains information on the preparation of reports which has never before been brought together and which will be useful for reference to those engaged in active practise. Various types of reports—information reports, examination reports, recommendation reports, progress reports and research reports—are analyzed systematically. The reports used are actual examples, selected from a great variety.

Recent Developments in Atomic Theory.

By Leo Graetz. N. Y., E. P. Dutton & Co., [1922]. 174 pp., illus., diagrs., tables, 9 x 6 in., cloth. $3.50.

Six lectures which explain the steps that lead up to present views about atoms and illustrate the advances in the explanation of many phenomena which have been made by means of these views. The book is intended not only for students of physics and chemistry, but also for general readers of a scientific turn of mind.

La Telegraphie Sans Fil.

By Julien Verdier. Paris, Gauthier-Villars et Cie., 1924. 412 pp., illus., diagrs., 9 x 6 in., paper. 35 fr.

This work is not a text on radio practice, but an account of the development of radio communication, intended for the general reader, in which the principles are explained and the great variety of uses to which it is being put are set forth. It gives for the first time, the author says, an account of the services rendered by radio during the World War; including among other items the hitherto unpublished official radiotelegrams concerning the armistice.

## Meeting of the Association of Russian Engineers

The Association of Russian Engineers is a society, recently organized according to the laws of the State of New York, devoted to the study of engineering progress in this country, as well as informing the membership of the engineering profession here of the progress of Russian technique.

The Association will hold its first open meeting on Friday, May 2nd at 8.00 p. m. in Room 3, Engineering Societies Bldg., 29 West 39th Street., New York City.

Frank B. Gilbreth will speak on "The Value and Aim of Scientific Management," and Walter N. Polakov will deliver an address on "The Progress of the Scientific Management Movement in Russia."

Members and guests of all engineering societies are cordially invited.

## PERSONAL MENTION

Robert C. Scott has severed his relations with the Union Gas & Electric Co. of Cincinnati and is now Electrical Designer with Stone & Webster, Boston, Mass.

Earl R. Evans, having left the employ of the North Electric Mfg. Co., is with the Patent Department, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

D. C. McClure, for several years associated with the Public Service Company of Colorado, is at present General Superintendent of the St. Joseph Railway, Light, Heat and Power Co., St. Joseph, Mo.

W. H. Patterson, formerly with the Resale-Industrial Sales Department, Chicago, Ill., is now connected with the John H. Dunham Company, Wrigley Building, Chicago, as Vice-President.

Yasudiro Sakai, registered patent attorney and consulting engineer, is now established at No. 2 Building, Fourth Floor, Marunouchi, C, Tokyo. His former offices were destroyed in the great disaster last September.

Leo Shapiro is connected with the Central Illinois Public Service Co., Springfield, Ill., as field engineer in the department of transmission and distribution. He was formerly with the Wagner Electric Corp., St. Louis, Mo.

Frank M. Reeves has joined The Triumph Electric Co., Cincinnati, Ohio. For the past four years Mr. Reeves was one of the power electrical engineers, connected with the Hawthorne Works of the Western Electric Co., Chicago, Ill.

William L. Laing has resigned his position as service engineer with the Champion Engineering Company of Kenton, Ohio, and is now employed by the Dominion Bridge Co., Lachine, P. Q., as designer and estimator in the Mechanical Engineering Dept.

B. H. Ormson, owing to the closing down of the mining properties of the Ruby Gulch Mining Co., has accepted a position with the Hecla Mining Co. of Wallace, Idaho. Mr. Ormson is engaged in installing new power equipment at its Burke, Idaho mines.

C. E. Reese, gas and electrical engineer, has been appointed General Manager of the Bluefield Gas & Power Co., Bluefield, W. Va. Formerly, he was Associate Editor of the Gas Age and Gas Age Record, and Editor of the Gas Engineering & Appliance Catalogue of New York City.

J. Allen Johnson will be connected with the firm of Harper & Taylor as electrical engineer. Mr. Johnson has been working for a number of years under Mr. John L. Harper on the Niagara Falls power projects. He was electrical engineer of the Ontario Power Company from 1903 until 1918, when he went with the Niagara Falls Power Company.

Hirsch Epstein resigned from the Hyperbo Electric Flow Meter Company, as production manager, and has formed his own company under the name of Epstein & Newman, manufacturing electro-medical apparatus. Mr. Newman was formerly developing engineer of the Hyperbo Electric Flow Meter Company. Offices are located at 1744 Ogden Avenue, Chicago, Ill.

John L. Harper, Vice President and Chief Engineer of the Niagara Falls Power Company, has announced with Mr. H. Birchard Taylor the incorporation of the firm of Harper & Taylor, with offices in the Bankers Trust Bldg., Philadelphia, Pa. and at Buffalo Avenue, Niagara Falls, N. Y. They will engage in the general practise of engineering, especially the investigation of water powers and the design, construction, operation and management of hydroelectric power projects.

## Obituary

Frank Eugene Kinsman, inventor of many well-known electrical devices, died at his home in North Leominster, Mass. on Feb. 5, 1924, following a general breakdown.

Early in his career he became General Manager of the Electric Construction and Supply Co., later being made President. He invented the telephone central office system in the winter of 1876-77 and while assisting in establishing a telephone system in Chicago, invented the multiple switchboard, which was sold to the Western Electric Co. He was the first to commercially introduce the arc lamp on low potential circuits, invented the Kinsman arc lamp for such circuits and the Kinsman block system. In 1892, he formed the Kinsman Block System Co., which owns his patents for automatically controlling the motive power and brakes on trains.

For many years Mr. Kinsman was associated with the late Alexander Graham Bell and with Thomas A. Edison. In 1892, he became an Associate of the Institute and in 1893 was transferred to the grade of Member.

# Past Section and Branch Meetings

### SECTION MEETINGS

**Akron.**—February 21, 1924, Perkins School Auditorium. Railway Electrification Meeting, joint with Board of Education. Subject: "Electrification of the Chicago, Milwaukee & St. Paul Railway." Speaker: Mr. J. A. Anderson. This lecture was illustrated with lantern slides and a two-reel film, entitled, "An Electric Ride over the Great Divide" was shown. Attendance 125.

**Baltimore.**—March 1, 1924, Club House, Holtwood, Pa. Joint meeting with Baltimore Section, A. S. M. E. Papers: "The Holtwood Power Development," by Mr. N. B. Higgins and Mr. R. L. Thomas, of the Pennsylvania Water and Power Co.; "Hydraulic Turbines and Draft Tubes," by Mr. F. H. Rogers of William Cramp & Sons Co.; "The New Holtwood Construction," by Mr. J. Walter May of Day & Zimmermann. An inspection trip was made to the McCalls Ferry Power House in Holtwood. Attendance 150.

**Cincinnati.**—February 14, 1924, Assembly Hall, Union Gas & Electric Company. Paper: "Elevator Control," by Mr. Oscar Shepard. This paper was well illustrated with lantern slides and a very active discussion followed. Attendance 39.

**Cleveland.**—February 21, 1924, Hotel Statler. Subject: "Recent Development in the Electrical Industry in the Far East." Speaker: Mr. Stephen Q. Hayes of the Westinghouse Electric and Manufacturing Company. The talk was illustrated by both slides and moving pictures. Attendance 50.

**Connecticut.**—February 15, 1924, Lampson Lyceum, Yale University, New Haven. Joint meeting with A. I. E. E. Yale University Branch. Subject: "The Electrical Transmission and Reproduction of Speech." Speaker: Mr. W. H. Martin of the American Telephone and Telegraph Company. Chairman Everit outlined briefly the growth and technical progress in the telephone industry from the days of Bell's first success to the present broadcasting of intelligence. Mr. Martin's discussion pertained to the problem of converting the speech sounds into electrical power at the sending end, and of getting speech sounds from the electrical power to the ear of the listener at the receiving end. A demonstration was made with a loud-speaking system with which filters were used to show the effect of eliminating different parts of the voice frequency range. Attendance 250.

**Denver.**—February 22, 1924, Adams Hotel. Paper: "Electric Cleaning of Gases from Iron Blast Furnaces by the Cotrell Process," by Mr. L. A. Seesz of the Colorado Fuel and Iron Company. The paper was very interesting and was discussed freely by those present. Mr. Hansen of the Reserve Corporation was present and took an active part in the discussion. Attendance 30.

**Detroit-Ann Arbor.**—February 15, 1924. Dr. Ernest J. Berg, Professor of Electrical Engineering, Union College, gave his "Personal Reminiscences of the late Dr. Charles P. Steinmetz." Dr. Berg told about Dr. Steinmetz' early life and surroundings, the human side of his career in this country, and his contributions to electrical science and to science in general. Attendance 85.

**Erie.**—February 19, 1924, Auditorium, Chamber of Commerce. Subject: "Transformers." Speaker: Mr. M. L. Elder of the General Electric Company. Moving pictures of the million-volt transformer in operation and explosion tests on transformers were shown; also a number of lantern slides. Attendance 225.

**Fort Wayne.**—February 21, 1924, Club Rooms, General Electric Company. Subject: "Production and Application of X-Ray." Speaker: Mr. C. N. Moore of the General Electric Company. The meeting was opened with comic and scenic movies.

March 12, 1924, Wayne Knitting Mills, Fort Wayne. Members of the Fort Wayne Section and ladies were entertained by the Wayne Knitting Mills. A portion of the Mills was in operation and those present were conducted through the Mills by officials and employees and were given an excellent opportunity to inspect the Mills. After the inspection, lunch was served in the recreational hall. Attendance 175.

**Indianapolis-Lafayette.**—February 15, 1924, Lincoln Hotel. Joint meeting with Indiana Engineering Society, American Society of Mechanical Engineers, American Association of Engineers and the Scientech Club. The evening was devoted to a dinner and dance with a talk just immediately following the dinner by Mr. Calvin W. Rice, Secretary, A. S. M. E., on the "Engineer in South America." The address was well illustrated with stereopticon views of South America. Attendance 100.

February 20, 1924, Lincoln Hotel. Subject: "High Tension Transmission." Speaker: Mr. C. L. Fortescue of the Westinghouse Electric and Manufacturing Company. Numerous questions were answered by Mr. Fortescue after his talk in a lively discussion participated in by members of the Section and visitors. Attendance 48.

February 29, 1924, Lincoln Hotel. Subject: "The Electricity Supply Industry and the Engineer." Speaker: Mr. R. F. Schuchardt of the Commonwealth Edison Company. Attendance 125.

**Ithaca.**—February 22, 1924, Sibley Dome, Cornell University. Subject: "The Niagara Falls Power Development." Speaker: Mr. J. L. Harper. Mr. Harper described many interesting points in the design, construction and erection of recent development at Niagara, and showed how further development would enhance rather than mar the beauty of the Falls. Attendance 230.

**Kansas City.**—January 25, 1924, Assembly Hall, Kansas City Power and Light Company. Joint meeting with the Engineers Club, National Electric Light Association, Electric Club and American Society of Mechanical Engineers. Subject: "The Cahokia Power Plant of the Union Light & Power Com-

pany of Illinois." Speaker: Mr. Eales. This talk was very educational and entertaining. Attendance 200.

**Lehigh Valley.**—February 8, 1924, Lehigh University-Commons. After a closing session of the Midwinter Convention, the Lehigh Valley Section arranged an inspection trip through the Bethlehem Steel Company's plant and a dinner at the Lehigh University Commons. After dinner addresses were made by President Richards of Lehigh University, welcoming the Institute members to the University. Dr. Richards dwelt on the advantages of the Lehigh University, showing that it was located in the center of the greatest industrial section of our country. President McCracken of Lafayette University also welcomed the visitors to Lehigh University. Interesting talks were made by Mr. L. W. W. Morrow, Professor Bedell of Cornell, Dr. Hering and Mr. Petty. Attendance 141.

**Los Angeles.**—January 31, 1924, Burdette Hall. Joint meeting with Southern California Telephone Company. Speaker: Mr. George B. Thomas of the Western Electric Company. Mr. Thomas delivered two lectures of about one hour each; the first one on the subject of "The Human Voice, Audition and Electrical Transmission," and the second one on "Telephone Cable History, Development, Design and Manufacture." Both lectures were illustrated with moving pictures and animated cartoons. Attendance 500.

**Lynn.**—February 12, 1924, Burdett Hall. Subject: "The Nature of Conduction in Nerves." Speaker: Dr. H. B. Williams of Columbia College of Physicians and Surgeons. Dr. Williams described in detail the functioning of the nervous system. Attendance 100.

February 20, 1924, G. E. Hall. The second local convention of the Lynn Section was held. Owing to an extremely severe storm, only a few were present but there was a good discussion of the papers by those attending. Refreshments were served. Attendance 35.

February 27, 1924, Classical High School Hall. Subject: "Japan." Speaker: Mr. Dana M. Wood. This was the second ladies night of the season. Mr. Wood illustrated his talk with a number of beautiful lantern slides colored by Japanese artists. He showed some views of the results of the last earthquake in Japan. Attendance 350.

March 11, 1924, G. E. Hall. Subject: "Heating Problems in Automobile Engines." Speaker: Mr. C. P. Grimes of the H. H. Franklin Manufacturing Company. In addition to Mr. Grimes' talk an interesting motion-picture film was shown, giving an outline of the electrical equipment of the ordinary gasoline automobile and its operation. Attendance 100.

**Madison.**—February 27, 1924, Engineering Building. Subject: "Crossing Bridges and Scaling Stone Walls." Speaker: Mr. C. E. Skinner of the Westinghouse Electric and Manufacturing Company. Attendance 30.

**Minnesota.**—January 23, 1924, Leamington Hotel. Dinner Dance. Attendance 125.

February 25, 1924, University of Minnesota. Subject: "Crossing Bridges and Scaling Stone Walls." Speaker: Mr. C. E. Skinner of the Westinghouse Electric & Manufacturing Company. Attendance 99.

**Philadelphia.**—February 6, 1924, Bellevue-Stratford Hotel. Illustrated lectures on 220,000-volt transmission were given by Mr. F. G. Baum of San Francisco. Attendance 450.

February 26, 1924, Drexel Institute. Joint meeting with the American Society of Mechanical Engineers. The meeting opened with an organ recital by Mr. Dickinson. President Matheson of Drexel Institute made a short address of welcome and Mr. W. E. Wickenden gave a very interesting talk on Engineering Education. A film entitled "Applications of Compressed Air" was also presented by Mr. Morrison. Attendance 350.

March 1, 1924, Engineers' Club. Joint meeting with the Association of Iron and Steel Electrical Engineers. Subject: "Effects of Heavy Short-Circuit Currents on Bus Structures." Speaker: P. T. Vanderwaart. A dinner preceded the meeting. Attendance 75.

**Pittsburgh.**—February 19, 1924, Chamber of Commerce. Subject: "Motor Ratings and Application." Speaker: Mr. C. A. Kelsey of the General Electric Company. Attendance 130.

**Pittsfield.**—February 14, 1924, F. M. T. A. Hall. Subject: "Automatic Stations and Supervisory Control Systems." Speaker: Mr. Chester Lichtenberg of the General Electric Company. Mr. Lichtenberg gave a very interesting talk dealing with the complete history of the development of the automatic substation. His talk was supplemented by means of lantern slides and motion pictures. Attendance 65.

**Portland.**—February 22 and 23, 1924. An excursion of the Portland engineers to the educational exposition and engineering show staged by the students of the Oregon Agricultural College was conducted. The trip was made by autos, traveling along the Pacific highway, a distance of about 100 miles up the Willamette Valley, and returning the same day. The visitors found many new buildings and new equipment. Attendance 50.

**Providence.**—February 29, 1924, Engineering Building, Brown University. Subject: "Color in Illumination." Speaker: Mr. Bassett Jones of Myers, Strong and Jones, Inc. The talk was very well illustrated by lantern slides. Following the talk a long discussion was held in which a large number of those present took part. Attendance 40.

**St. Louis.**—December 18, 1923, Engineers' Club. Subject: "Recent Developments in Electric Metering." Speaker: Mr. R. C. Lamphier of the Sangamo Electric Company. Mr. Lamphier's talk was very instructive as well as interesting. Attendance 53.

January 30, 1924, Engineers' Club. Joint meeting, under auspices of the A. I. E. E., of the Associated Engineering Societies of St. Louis. Subject: "Automatic Train Control." Speaker: Mr. H. B. Mann of the Missouri Pacific Railway Company. This talk was ably presented by the speaker and with the aid of animated motion pictures the actual operation was clearly demonstrated. Attendance 106.

February 1, 1924, Chamber of Commerce. Joint meeting with St. Louis Section of the A. S. M. E. Subject: "Use of Central Station Energy in Southern Illinois Coal Fields." Speaker: Mr. J. D. Roberts of the Central Illinois Public Service Company. A dinner preceded the meeting. Attendance 130.

**San Francisco.**—February 29, 1924, Engineers' Club. Subject: "Measurements of Surges in Power Transmission and Distribution Lines," by Mr. A. W. Copley and J. F. Peters. Mr. Copley illustrated his talk with numerous lantern slides. Attendance 95.

**Schenectady.**—February 1, 1924, Edison Club Hall. Subject: "The Fundamentals of High-Voltage Phenomena." Speaker: Professor Harris J. Ryan, President of the A. I. E. E. Professor Ryan showed some very interesting features occurring in high-voltage studies. Attendance 280.

February 15, 1924. Edison Club Hall. Subject: "Electric Drive for Central Station Auxiliaries." Speakers: Mr. E. E. Thomas, Mr. J. W. Dodge and Mr. H. L. Smith. A very interesting discussion followed in which Messrs. W. L. R. Emmet, P. L. Alger, H. R. Summerhayes and M. J. Lowenbery of Stone & Webster, took part. Attendance 180.

**Seattle.**—February 20, 1924, Engineers' Club. Subject: "Theory of Relativity." Speaker: Dr. E. T. Bell of the University of Washington. After the close of the lecture discussions were entered into by Dr. Magnusson, Messrs. Quinan, Whipple, Watson, Rader and LeFever. Attendance 96.

March 3, 1924, Engineers' Club. Subject: "Crossing Bridges and Scaling Stone Walls." Speaker: Mr. C. E. Skinner of the Westinghouse Electric and Manufacturing Company. Attendance 60.

**Spokane.**—December 27, 1923, Telephone Building. An inspection of telephone-exchange equipment was made through the courtesy of the Home Telephone and Telegraph Company. Men in charge of the various departments explained the operation of the apparatus. Attendance 25.

February 8, 1924, Davenport Hotel. Subject: "Some Reasons Why." Speaker: H. V. Carpenter, Dean of Mechanic Arts and Engineering, State College of Washington. Attendance 35.

**Springfield.**—February 14, 1924, Highland Hotel. Subject: "Domestic Electricity." Speaker: Mr. G. H. Garcelon of the Westinghouse Electric and Manufacturing Company. Movies and stereopticon accompanied the lecture. Dancing followed. Attendance 83.

**Toledo.**—February 20, 1924, Chamber of Commerce. Subject: "High-Tension Transformer Substations." Speaker: Mr. Paul Bailey of the Ohio Power Company. The lecture was illustrated with blue prints and lantern slides. An extensive discussion made the meeting a very interesting one. Attendance 70.

**Toronto.**—February 15, 1924, Electrical Building, University of Toronto. Subject: "Recent Developments in Prime Movers, Using Steam, Oil and Water." Speaker: Professor R. W. Angus. A number of very interesting slides was shown. Attendance 70.

February 29, 1924, Electrical Building, University of Toronto. Subject: "The Distribution Features of the Toronto Hydro Electric System." Speaker: Mr. P. E. Hart of the Toronto Hydro Electric System. A large number of slides was shown giving detailed views of the distribution system. Attendance 107.

**Urbana.**—February 15, 1924, Physics Lecture Room, University of Illinois. Subject: "The Electrical Investigation of Speech and Audition." Speaker: Mr. John Mills of the Western Electric Company. The lecture was very instructive and entertaining and was exceedingly well received. Attendance 210.

February 21, 1924, University of Illinois. Subject: "New Problems in Power Transmission." Speaker: Mr. R. E. Doherty of the General Electric Company. The lecture was illustrated by slides. Many new and unexpected phases of the problem were accurately and entertainingly presented. Attendance 150.

**Vancouver.**—March 7, 1924, Bodwell Automatic Substation. Subject: "Automatic Substation Operation." Speaker: Mr. R. L. Hall. By means of diagrams and actual demonstration, Mr. Hall described very fully the functioning of various portions of the equipment of a 1000-kw. Automatic Railway Substation recently built by the B. C. Electric Railway Company. Attendance 50.

**Washington.**—February 12, 1924, Cosmos Club. Subject: "Lighting Practise as Influenced by Recent Developments." Speaker: Mr. C. E. Weitz of the National Lamp Works. The lecture was accompanied by lantern slides and a demonstration of lighting effects and lighting apparatus. Attendance 153.

February 26, 1924, City Club. Luncheon Meeting. Subject: "Alaskan Cable." Speaker: Lieut. Col. C. A. Sloane, Signal Corps, U. S. A. Attendance 27.

**Worcester.**—March 6, 1924, Worcester Polytechnic Laboratory. Subject: "The Davis Bridge Development." Speaker: Mr. A. C. Eaton of the New England Power Company. The speaker showed, by lantern slides and detailed description, the construction of the highest dirt dam in the world. Attendance 225.

## BRANCH MEETINGS

**Alabama Polytechnic Institute.**—February 13, 1924. Subject: "A Review of Electrical Progress in 1923.", Speaker: Mr. P. S. Timberlake. In the latter part of the meeting Mr. L. R. Housel was elected Secretary to succeed Mr. J. W. Bates, resigned. Attendance 35.

February 27, 1924. A two-reel Westinghouse picture "Electrified Travelogue" was shown, which proved to be very interesting. Attendance 29.

**University of Alabama.**—March 6, 1924. Subject: "Telephone Communication in the Army." Speaker: Mr. C. M. Lang. Attendance 10.

**University of Arizona.**—February 13, 1924. Six reels of educational moving pictures were shown. Attendance 15.

**University of Arkansas.**—January 30, 1924. Subjects: "Safety Standards in G. E. Plants," by Mr. A. E. Stevenson; "High-Voltage Insulation," by Mr. C. T. Marak, and "Starting of Polyphase Motors," by Mr. H. L. Cox. Attendance 17.

February 13, 1924. Subjects: "Niagara Falls Generators," by Mr. J. A. Cunningham; "Three-Electrode Vacuum Tube," by Mr. R. C. Mason, and "Avoidable Waste in Locomotives," by Mr. C. E. Bowman. Attendance 13.

**Armour Institute of Technology.**—March 6, 1924. Subject: "Railway Train Lighting." Speaker: Mr. Waver, a student. Mr. Waver spoke on his experiences as a repair man in the Train Lighting Branch of the Pullman Company. Attendance 15.

**California Institute of Technology.**—March 5, 1924. Subject: "Reduction of Magnetic Iron Ore." Speaker: Mr. Lutes, a student. Attendance 25.

**University of California.**—February 13, 1924. Subject: "Modern Telephone Problems." Speakers: Messrs. W. C. Smith, R. K. Maynard and Moss of the Pacific Telephone and Telegraph Company. Refreshments were served. Attendance 58.

February 27, 1924. An inspection trip was conducted through the plant of the Pacific Telephone and Telegraph Company. Guides were provided by the company. Attendance 64.

**Catholic University of America.**—February 21, 1924. Subjects: "Some Phases of the Development of the Art of Communication," by Mr. J. L. Vandegrift; "Interesting Points on Radio Broadcasting," by Mr. L. F. Voorhees, and "History of the Telephone" (illustrated), by Mr. L. A. Waters. After the meeting refreshments were served and a short smoker held. Attendance 37.

**University of Cincinnati.**—January 24, 1924. Subject "Location of Troubles in Power Cables." Speaker: Mr. H. G. Stamper. Attendance 40.

January 31, 1924. Subject: "Radio Repeating Stations.' Speaker: Mr. Grafton Smith. Attendance 40.

February 14, 1924. Subject: "Some Tests on Station Grounds." Speaker: Mr. Jack Clagett. Attendance 28.

February 21, 1924. Subject: "History of Electric Motors" (illustrated). Speaker: Mr. R. T. Cougleton. Attendance 32.

February 28, 1924. Subject: "Current-Transformer Testing." Speaker: Mr. Sam Aronoff. Attendance 30.

March 3, 1924. Subject: "Great Lake Navigation." Speaker: Mr. H. E. Sanford. Attendance 25.

**Clarkson College of Technology.**—February 12, 1924. Business Meeting. Attendance 15.

February 26, 1924. Two motion pictures were shown; one of the Westinghouse Works, and the other on Railroad Electrification. Attendance 47.

**Clemson Agricultural College.**—February 28, 1924. Subjects: "Water Power Engineering," by Mr. F. F. Dean; "Hydro-Electric Systems in the Southeast," by Mr. J. H. Sams, and "New Developments in the Southeast," by Mr. R. W. Pugh. Attendance 22.

March 12, 1924. Two Westinghouse moving pictures were shown and discussed—"Rolling Steel by Electricity" and "An Electrified Travelogue." Attendance 51.

**Colorado State Agricultural College.**—February 24, 1924. Subject: "The Capacity of the Hydroelectric Generator at Niagara Falls." Speaker: Mr. Sinnock. Attendance 10.

**University of Colorado.**—February 7, 1924. Subjects: "Personal Experiences with Steinmetz," by Mr. B. C. J. Wheatlake, and "Reasons for Automatic Substations," by Mr. A. S. Anderson. Both speakers were from the Denver Office of the General Electric Company, which presented the Branch with a framed picture of Dr. Steinmetz. Motion pictures and slides were shown on "Automatic Switching Equipment for Substations." Attendance 80.

**University of Florida.**—February 27, 1924. Organization Meeting. Election of officers as follows: Chairman, Dean J. R. Benton; Secretary, George Harrison. Attendance 13.

**University of Iowa.**—February 11, 1924. Subject: "Electrolysis of Underground Metals." Speaker: Mr. L. Benetier, student. Attendance 23.

February 18, 1924. Subjects: "Early Developments of the Arc Light," by Mr. H. D. Brockman; "Dam Project of the Colorado River," by Mr. P. E. Chrestenson; "Power House of International Paper Co.," by Mr. G. Cox, and "Some Electric Developments of 1923," by Mr. J. Dautremont. Attendance 41.

February 25, 1924. Subjects: "Sleet and Ice Formation on Trolley and Transmission Lines," by Mr. R. L. Fox, and "Power Drive," by Mr. H. C. Halweg. Attendance 43.

March 3, 1924. Subjects: "New Developments of the Submarine Cable," by Mr. F. M. Jennings; "Advantages of Electric Furnace over the Gas Furnace," by Mr. A. M. Hanson, and "The World's Largest Hydro-Electric Generator," by Mr. L. W. Jansa. Attendance 48.

**Kansas State College.**—January 21, 1924. Subject: "From Pit to Roof." Speaker: Mr. Edgar L. Misegades. Attendance 50.

February 11, 1924. Subject: "Railway Signaling on Santa Fe R. R." Speaker: Mr. V. O. Clements. Attendance 58.

February 18, 1924. Subject: "The History of the Science of Mechanics." Speaker: Prof. J. H. Robert. Attendance 43.

**University of Kentucky.**—February 28, 1924. Subject: "Insulation." Speaker: Professor E. A. Bureau. Attendance 32.

**Lafayette College.**—February 9, 1924. Subject: "Bell Telephone System." Speaker: Professor King. Attendance 19.

February 13, 1924. Inspection Trip to the Central Office of the Bell Telephone Company in Easton, Pa.

**Lehigh University.**—February 28, 1924. Subjects: "Handling Telephone Traffic in Metropolitan Areas," by Mr. C. A. Alford; "Telephone Transmission," by Mr. L. C. Wurster, and "Electric Shovels," by Mr. E. L. Robinson. All the speakers are students of the University and the papers were thoroughly presented. Attendance 35.

**Michigan Agricultural College.**—February 18, 1924. Subjects: "Relays," by Mr. Riggs and "Practical Use of Relays," by Mr. Anderson. Both speakers were from the Lansing Municipal Power Plant. Attendance 40.

**Engineering School of Milwaukee.**—February 29, 1924. Mr. D. C. Hatton, Chief Engineer of the Milwaukee Sewage Commission, gave a very interesting lecture on the great engineering difficulties which were overcome during the building of the first trans-continental railroad, namely, the Union Pacific and the Central Pacific. Attendance 31.

**University of Minnesota.**—February 13, 1924. Subject: "The Engineer as a Telephone Prophet." Speakers: Mr. H. C. Evarts and Mr. Kingsley. Refreshments were served. Attendance 48.

February 29, 1924. Subject: "New Problems of Long Transmission Lines." Speaker: Mr. R. E. Doherty of the General Electric Company. Attendance 230.

**University of Nevada.**—February 26, 1924. Mr. Robert Balzari, Manager Industrial Division of the Westinghouse Electric and Manufacturing Company, San Francisco, gave a very interesting talk on the work of the Westinghouse Company in the educational field, especially in regard to their training of college graduates. Attendance 30.

**North Carolina State College.**—February 12, 1924. Subject: "The Employment of the Engineering Graduate." Speaker: Dr. H. B. Shaw. Dr. Shaw gave the members a good idea of the requirements of various engineering and manufacturing companies. There was also a discussion of consolidation of all engineering "shows" into one, all department of engineering participating. Attendance 16.

**University of North Dakota.**—February 14, 1924. Joint meeting with A. S. M. E. Subject: "Power Factor and Efficiency." Speaker: Mr. H. E. Brown, student. A moving picture was also shown, entitled "Westinghouse, The Institution." Attendance 38.

**Northeastern University.**—February 20, 1924. Subject: "Radio-Frequency Amplification and Reflex Action." Speaker: Mr. C. Dallen of the Acme Apparatus Company. Attendance 51.

**Ohio Northern University.**—February 13, 1924. Subjects: "Locomotive Headlight Equipment," by Mr. R. Young, and "Salesmanship," by Mr. Wm. German. Plans were made for the Annual Spring Smoker. Attendance 22.

**Ohio State University.**—February 1, 1924. Subject: "The Human Factor in Industry." Speaker: Mr. H. H. Craiglow. Attendance 21.

**University of Oklahoma.**—December 2, 1923. Professor Tappan gave an interesting talk on the life of Dr. Steinmetz. Refreshments were served. Attendance 23.

January 10, 1924. As there was no business to be taken up, the meeting adjourned and those present attended a lecture at the Engineers' Club on "Highway Engineering." A motion picture on "The Making of an Automobile Engine and How It Operates" was also shown. Attendance 23.

February 21, 1924. Two motion pictures were shown; one on "Wireless and Its Operation," and the other on "The Achievements of Thomas A. Edison." Attendance 26.

**Pennsylvania State College.**—February 21, 1924. Subject: "The Engineering of Automatic Telephone Switching." Speaker: Mr. E. H. Goldsmith. Attendance 72.

**University of Pennsylvania.**—February 22, 1924. Business Meeting. Mr. R. R. Osborn was elected Vice-President to succeed Mr. J. G. Smith who had left college. Mr. D. Keiser, a member of the faculty, demonstrated a few interesting laboratory experiments, after which refreshments were served. Attendance 44.

**University of Pittsburgh.**—February 15, 1924. Subject: "Lightning Arresters," (illustrated), by Mr. G. J. Read. Attendance 24.

February 29, 1924. Mr. R. S. McCarthy, Asst. to Vice-President of Duquesne Light Co., gave a general talk for engineers, discussing the engineer in business, desirable qualifications and the proper selection of a profession. Attendance 20.

March 7, 1924. Subjects: "Qualities of an Engineer," by Mr. L. F. Blassingham, and "Test Course at G. E. Co. Schenectady Works," by Mr. H. A. Neish. Attendance 20.

**Purdue University.**—February 13, 1924. Subject: "The Latest Developments in the Field of Electrical Power Distribution on Large Scales" (illustrated). Speaker: Mr. G. L. Jensen of the Consumers Power Company. Attendance 70.

February 20, 1924. Subject: "What the Telephone Transmits and How We Hear It" (illustrated). Speaker: Dr. John Mills of the Western Electric Company. Attendance 76.

**Rensselaer Polytechnic Institute.**—February 19, 1924. Subject: "Recent Developments in Alloy Research." Speakers: Dr. M. A. Hunter, Dr. R. A. Patterson and Mr. A. L. Taylor

of the Department of Electrical Engineering. A number of slides was shown. Attendance 104.

**University of Southern California.**—February 13, 1924. Subject: "High-Tension Transmission Lines." Speaker: Mr. Blossom of the Southern California Edison Company. Attendance 9.

**A. & M. College of Texas.**—February 15, 1924. Subjects: "The Flynn-Weichel Motor," by Mr. Williams, and "The Electrification of the Logging Industry," by Mr. E. E. Ewbanks. Both talks were interesting and instructive. Plans were made for a smoker. Attendance 50.

February 29, 1924. Subjects: "The Operation of the Watt-Hour Meter," by Mr. Smith, and "The Electrification of the Chicago, Milwaukee and St. Paul Railroad," by Mr. John Miles. Refreshments were served. Attendance 80.

**State College of Washington.**—January 23, 1924. Election of officers as follows: President, Jake Dunkin; Vice-President, Phillip Fridlund; Secretary, J. Yasumura; Treasurer, Geo. R. Fellers; Reporter, Loren A. Traub. Illustrated paper on "Westinghouse, the Institution" was read by Dean Carpenter. Attendance 60.

February 13, 1924. Plans for Reorganization. Professor R. D. Sloan gave a talk on "Benefits of Being a Member of the National A. I. E. E." Attendance 35.

**University of Washington.**—March 3, 1924. Subject: "The Executives of the Westinghouse Company and Their Work." Speaker: Mr. C. E. Skinner of the Westinghouse Electric and Manufacturing Company. Attendance 93.

**West Virginia University.**—February 27, 1924. Subjects: "Electrical Communications," by Mr. Hall; "Manufacturing Built-up Mica," by Mr. Devebre; "Interconnections of Transmission Lines," by Mr. Robinson; "Development in Size of Generative Equipment," by Mr. Brown; "Radio Communication by Use of Short Wave Lengths," by Mr. Kisner; Development in Lighting and Starting of Motor-Driven Vehicles," by Mr. Mountain; "Impetus to Electrical Cooking," by Mr. Hill; "Vapor Detector Tubes," by Mr. Wolfe, and "Voltage Control of Long High-Tension Lines by Synchronous Condensers," by Mr. Kellerman. Attendance 33.

**University of Wisconsin.**—January 23, 1924. Business Meeting. Election of officers as follows: Chairman, H. A. Holmes; Executive Committee, T. King and A. Pokras; Secretary, Kent Wooldridge. Attendance 27.

February 20, 1924. Business Meeting. Attendance 28.

February 28, 1924. Joint Meeting with A. S. M. E. Subject: "Mathematics and the Engineer." Speaker: Mr. R. E. Doherty of the General Electric Company. Attendance 50.

**Yale University.**—February 26, 1924. Subject: "The Nuclear Atom." Speaker: Associate Professor A. L. Kovarik. Attendance 40.

March 4, 1924. Subject: "The Evolution of Ships." Speaker: Professor R. S. Lull. Attendance 45.

March 7, 1924. Subject: "Kilovolt-Ampere Metering" (illustrated). Speaker: Mr. B. H. Smith of the Westinghouse Electric and Manufacturing Company. Attendance 70.

# Engineering Societies Employment Service

*Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers as a cooperative bureau available only to their membership, and maintained by contributions from the societies and their individual members who are directly benefited.*

*MEN AVAILABLE.—Brief announcements will be published without charge and will not be repeated, except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to* ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th of the month.*

*OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.*

*VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will, it is hoped, be sufficient, not only to maintain, but to increase and extend the service.*

*REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case and with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.*

*(For other employment announcements see page 47 of the Advertising section.)*

### POSITION OPEN

CHIEF ELECTRICAL ENGINEER, to take complete executive charge of the electrical engineering department for a utility owning a number of high-tension central stations. Must have been employed very recently in similar capacity or have lately held responsible electrical engineering position with large manufacturer of electrical central station equipment. Salary $7500 a year, minimum. R-3525.

GRADUATE ELECTRICAL ENGINEER for editor of trade paper. Editorial experience essential, engineering and construction experience also desirable. Application by letter giving details of experience. R-3553.

### MEN AVAILABLE

MECHANICAL AND CONSTRUCTION ENGINEER, age 42, married. Over 20 years in responsible charge of design, construction, operation and maintenance of heavy machinery, steam and electric power stations, chemical manufacturing plants in America and foreign countries. Good executive. At present employed but desires position of greater responsibility and opportunity. Any location. Available on reasonable notice. B-7433.

ELECTRICAL - MECHANICAL ENGINEER—Technical education. Fifteen years' experience in Latin America in construction, operation and maintenance. Thorough knowledge of Spanish. Working knowledge of French and German. Possesses some knowledge of selling and purchasing. B-7425.

ELECTRICAL AND TELEPHONE ENGINEER with twenty years' experience in engineering, construction, operation and maintenance of telephone plants; outside distribution and inside installation of light and power, thoroughly practical and a producer of results, desires position with opportunities. Spanish and French spoken a little, available after November 15, 1924, salary around $4000, references exchanged. B-7512.

ELECTRICAL ENGINEERING GRADUATE, age 26, fifteen months on G. E. Test and one year of construction and engineering at

G. E. district office. Desires connection with construction or consulting engineers in western states. Only position having hard, steady work and chance to start from the bottom will be considered. B-7529.

GRADUATE ELECTRICAL ENGINEER, age 32, married. Two years' experience on test floor of Westinghouse Company. Two years electrical engineer for an industrial firm. Two years with a power company on commercial and distribution work. Past year on design and layout of power plant and substation. Desires position of a permanent nature with public utility company. B-3018.

ELECTRICAL ENGINEER - EXECUTIVE, 38, with 17 years' experience in design, construction and operation of power and substations, industrial buildings, transmission systems, radio stations, electrolysis surveys, handling scientific research problems in connection with electromagnetical apparatus, illumination and dielectrics, appraisals of plants and handling costs and operating characteristics of electrical and mechanical apparatus. B-3954.

ELECTRICAL ENGINEER, Cornell University M. M. E., age 46, married. Past 14 years with large manufacturing company. Broad experience in design, application and sales of electrical apparatus and in training men for sales engineering, desires position as professor of electrical engineering with privilege of some consulting engineering practise. Excellent references from present position. B-7209.

SALES ENGINEER, 26, single, M. I. T. 1918, electrical engineering, open for new connection. Sales experience three years along electrical lines, with prior engineering experience in steam power plants (marine). Last year and a half sales engineer and supervisor of other salesmen. Available on one week's notice. B-2225.

AVAILABLE in middle west or east, an engineer and executive of established reputation and nineteen years' experience manufacturing, designing and selling on motors, generators, controllers and on cranes, hoists and material handling. Seven years' college training and broad business experience. B-5379.

ELECTRICAL - MECHANICAL ENGINEER, 33, married, technical electrical graduate, 11 years' experience coal mining, railway, and industrial work, available on short notice. Capable and responsible to manage a business, a branch sales office, or an engineering and maintenance department. B-7563.

GRADUATE ELECTRICAL AND MECHANICAL ENGINEER, American. 30 years' experience including 3 years apprenticeship in General Electric Company Shops. Experience covers steam and water power production, transmission line operation and construction, municipal and commercial lighting, urban and interurban railway operation, and shops, carbarns and testing laboratories. Positions held range from linemans helper to general superintendent of electrical department of one of the largest hydroelectric systems in United States. B-7571.

ELECTRICAL ENGINEER, 31, married. B. S. degree, Pennsylvania, 1916. Eight years' practical engineering experience. Railway signalling, 2½ years with manufacturing and R. R. companies. Commissioned Army Service, 2 years. Four years electrical contracting on large work as superintendent, estimator, designer, buyer. Service and repair work industrial plants. Available April 1st. B-7569.

ELECTRICAL ENGINEERING GRADUATE with four years' experience in teaching electrical engineering in a high grade middle western university and one year's experience in steam engineering in the U. S. N. desires position in operating or distributing department of a flourishing electric utility. Location not of prime importance. B-7598.

EXECUTIVE ENGINEER, college graduate, single, age 30. Experience, construction and design, indoor and outdoor, substation transportation system. Transmission and distribution, overhead and underground. Survey and appraisal of utility properties. Spanish, Portuguese, some French. Best reference. B-7599.

TECHNICAL GRADUATE, 1915, G. E. Test. Desires position covering investigations, reports and recommendations in connection with method of supply or application of electricity in industrial plants, including formulation of plans and specifications. Salary commensurate with ability and experience. B-7532.

POWER DISTRIBUTION, TRANSMISSION, GENERATION. Electrical engineering teacher several years, three years with G. E. Company test. Now employed at good salary. Age 34, college man, seasoned ability. Am looking for man-size job as operating, construction or maintenance engineer and can handle it. Available 20 days. B-7614.

M. I. T. graduate 1922, experience in power sales promotion, commercial and business relations in power service work of central station company of installations ranging up to 250 h. p. desires an opportunity where engineering education and business experience as outlined, in this or other fields will be of use. B-6509.

ASSOCIATE A. I. E. E. University graduate with high honors, trained by G. E., wants transmission line calculation or similar position with power corporation. Preferably in West. Experienced. B-7623.

INSTRUCTOR, B. S. in Engineering. Age 26, three years' experience teaching electricity and radio in High School and electrical engineering in Junior College and two years' experience in telephone work, desires summer job with opportunity for permanent position. Available June 15th. B-7629.

GRADUATE, E. E. Age 26. Sixteen months on G. E. test. Two years practical electrician and foreman. Latter included switchboard wiring, motor and transformer installation, remote control starting and switching connections in conduit, underground cable and pole line transmission; mine haulage, lighting, signal power and telephone work. Employed but would like greater opportunity. Favor construction work, preferably in electrifying steam roads. B-7637.

POSITION WANTED with Public Utility, contractors or engineers. 8 years, 110-kv. line location, engineering, inspection, live line maintenance and new construction, pole lines, etc., reports, time studies. 8 years engineering, supervision, estimating, textile and mill power and illumination. 1 year appraisal Public Utilities. 3 years hydro-plant and sub-station construction. B-5347.

ELECTRICAL ENGINEER, fifteen years' experience. Served General Electric Company nine years. Two years in testing, five years in switchboard design, application and sales, two years in power and substation design. Also had four years' consulting engineering and contracting experience, and two years in coal mining industry. Knowledge of design and application of mill drives, hoists, pumps, fans, electric mining locomotives, etc. Age 35, married, family. B-5674.

GRADUATE ELECTRICAL AND MECHANICAL ENGINEER, Assoc. A. I. E. E. Member S. A. E., age 31, single. Unusually broad experience in design and production of control apparatus, industrial haulage equipment, storage battery locomotives, trucks, tractors and trailers. Holding responsible position with charge of design for the last five years with two of the largest manufacturing companies for industrial haulage equipment. Desires position of greater responsibility with reliable organization. Location immaterial. B-7250.

ELECTRICAL ENGINEER, with considerable and successful record in the development of intricate electro-mechanical problems. Has been accustomed to make a theoretical analysis, preliminary commercial survey and carrying out of experiments, design, construction and patent routine. E. E. and M. E. degrees. Highest credentials available. Fourteen years of practise here and abroad. Resident of New York City, position desired in New York City. Married, 38. Minimum salary $4800. A-165.

HYDRO-ELECTRIC DESIGNER, available on two weeks' notice Graduate engineer, 33, familiar with design of pulp and paper mills. Present salary $3300. A-3702.

FORESTER-LAWYER, studied at two forest schools and law school graduate. Studied commerce one year at university. At present engaged in graduate study of economics as related to forestry at an eastern university. Desires to locate with a forest products concern where a knowledge of both law and forestry will be useful. Interview desired. Available June 15th. B-7646.

ELECTRICAL ENGINEER for public utility office, engineering firm or industrial concern, where I can get a good experience in design and management of power and industrial plants. Initial salary and location secondary, but would prefer New York, Philadelphia or Illinois. Desire a good prospect of having a wide experience and practise. B-5295.

ELECTRICAL ENGINEER, college graduate, age 32. Westinghouse students training course, engineering and sales experience, is seeking a connection with an American firm engaged in export trade in engineering or sales capacity. Traveled extensively in western Europe, Russia and Far East. Speak Russian and German. Character and ability references the best. Correspondence solicited. B-3993.

ELECTRICAL ENGINEER with ten years' switchboard and panelboard design experience. Five as chief engineer with company manufacturing these and similar products. Familiar with circuit breakers, switches, instruments and relays. Working knowledge of power plant and substation design, and two years' architectural experience. Can design complete electrical systems for buildings, including stage and auditorium lighting systems. Age 30, married. B-7665.

MAINTENANCE ENGINEER, University training electrical engineer. Moving from Pittsburgh to Massachusetts May 1st. Desires connection with utility or company in or near Boston. Nine years' practical experience in maintenance, inspection and estimating on light, power and telegraph work. Age 30, married. Any reasonable proposition which offers opportunity for advancement will be considered. B-7664.

GRADUATE ENGINEER M. E. and E. E. 5½ years' experience covering construction, testing, inspection and operation of power plants and substations. 3½ years assistant editor for technical paper. Reading and speaking knowledge of French and German. Captain during war, with A. E. F. for two years, designing and building special radio equipment. Good initiative and ability. Desires position as electrical inspector or responsible position with engineering and construction company. B-7514.

CONSTRUCTION ENGINEER, 13 years' experience in construction and design of power station. Desires to locate in southern states as construction engineer, or similar position with a public utility company. Can handle either new construction or maintenance work. Available in ten days. Salary $3600 per year. B-7655.

GRADUATE ELECTRICAL ENGINEER with eight years' experience in electric utility work, wishes to affiliate with a progressive power company, preferably in the middle west. Desires a responsible position with good opportunity for advancement. Distribution engineering work of executive character would be preferred. B-7585.

SUMMER EMPLOYMENT, Electrical Engineer, desires position from June 10th to Sept. 20th. Construction work in New York State preferred. Experience; 3 years instructing in junior and senior courses at Cornell, 1 year in Engineering Department of the Philadelphia Electric Company, 2 summers in the Westinghouse Branch Office at Buffalo and 1 summer in the Engineering Department of the Buffalo General Electric Company. Salary $200 a month. B-7496.

GRADUATE ELECTRICAL ENGINEER. Six years' practical experience, including four years with large manufacturer on central station switching equipment, two years design and construction of central stations. Can produce results. Desires position in central west where initiative and Yankee ingenuity will lead to advancement. B-7670.

ELECTRICAL ENGINEER, age 28, graduate of M. I. T. Four years part time with civil engineer, two years transmission engineer and assistant superintendent of distribution with power company having 50,000 services; now with engineering company. Position wanted covering design and construction of distribution and transmission lines and manual and automatic substations. Available 15 days' notice. B-7663.

INSTRUCTOR of electrical engineering during the past four years in high grade middle west engineering college. One year of research work. B. S. in E. E. 1917 and M. S. in E. E. 1920. Associate A. I. E. E. Member of Sigma Xi. Age 30, married. Due to lack of changes in department, no immediate chance for advancement here. Willing to go elsewhere as associate or assistant professor. B-7223.

PHYSICIST - ELECTRICAL ENGINEER, graduate with B. S. (E. E.) 1919 and M. S. (Physics) 1921. University instructor in mathematics for two years. At present on a scholarship at Oxford. Will finish research in electrical physics for a D. Phil. in June 1924. Desires a position either teaching physics in a university offering opportunities for advancement and facilities for research or with a company conducting advanced electrical research. Available after September 15, 1924. American, age 26. B-7689.

ELECTRICAL AND TELEPHONE ENGINEER with twenty years' experience in engineering, construction, operation and maintenance of telephone plants, outside distribution and inside installation of light and power, thoroughly practical and a graduate in electrical engineering. Spanish and French spoken a little, available after November 15, 1924. Salary around $4000. B-7512.

ELECTRICAL ENGINEER, 20 years manager of a state telephone research laboratory, desires position as researcher in ocean and intercontinental telephony, rapid telegraphy, by sound governed automatic torpedoes, insulation research, (rubber, porcelain), superline transmission with shunt coils, radio, public address, speaking kinos. Speaks and writes English, French, German, Hungarian, understands and reads Spanish, Italian. Minimum salary $3600. B-6561.

GRADUATE ELECTRICAL ENGINEER, age 38 years with 5 years' broad, varied power station experience covering all phases of testing construction and maintenance. 8 years on field work covering line construction, estimates and electrolysis investigations. Present salary $3000. B-7701.

FOREIGN SERVICE or construction work anywhere, wanted by graduate electrical engineer. Age 24. Two years' experience estimating, bidding and purchasing for large contracting firm, building power and light plants, water works and transmission lines. Employed at present but available on fair notice. B-7699.

# MEMBERSHIP — Applications, Elections, Transfers, Etc.

**ASSOCIATES ELECTED MARCH 14, 1924**

*AGER, RAYMOND WELLINGTON, Inspector, Southern California Edison Co., 1201 W. 2nd St., Los Angeles, Calif.

AHMED, SHAIKH MUZAFFAR, Asst. Engineer, Receiving Station, Tata Hydro-Electric Power Supply Co., Parel, Bombay, India.

ALLAIN, GEORGE OCTAVE, Jr., Transmission Engineer, Cumberland Tel. & Tel. Co., Nashville, Tenn.

ALVERSON, GEORGE S., Electrical Engineer & Draftsman, Rochester Gas & Electric Corp., 13 Graves St., Rochester, N. Y.

ANDREWS, JOHN L., Electrician, Union Gas & Electric Co., 1107 Plum St., Cincinnati, Ohio.

ARCAUTE, JOSEPH ALBERT, Engg. Assistant, The New York Edison Co., 130 E. 15th St., New York, N. Y.

AZOVSKY, ZENOBE, Construction Dept., Rotterdam Substation, Adirondack Power & Light Corp., Schenectady, N. Y.

BARDWELL, HAROLD FOSTER, Electrical Engineer, Westinghouse Elec. & Mfg. Co., Page Blvd., East Springfield, Mass.

*BARNSDALE, GARNETT H., Fieldman, Pacific Tel. & Tel. Co., 740 S. Olive St., Los Angeles, Calif.

BARTLEY, EDWARD WILLIAM, Sales Engineer, Century Electric Co. of St. Louis, 30 Church St., New York, N. Y.

*BEAUMAN, L. ROY, Electrical Distribution Engineer, Illinois Power & Light Corp., Decatur, Ill.

BEE, EUGENE SEAVEY, Chief Engineer, State Sanatorium, Sanatorium, Miss.

BEEDE, CARL H., Load Dispatcher, City Lighting Dept. of Seattle, 7th Ave. & Yesler Way, Seattle, Wash.

BEETH, WALTER GERALD, Experimental Tester, General Electric Co., 1600 Broadway, Ft. Wayne, Ind.

*BERRY, HARVEY ROSEBRUGH, Transmission Engineer, Pacific Tel. & Tel. Co., 835 Howard St., San Francisco; res., Berkeley, Calif.

*BHUSHAN, VIDIYA, Student, Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

*BISHOP, GEORGE MALLORY, Electrical Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.

BONN, ARTHUR EUGENE, President, A. E. Bonn & Co., Inc., 501 Fifth Ave., New York, N. Y.

BOSSART, PAUL N., 7403 Schoyer Ave., Swissvale, Pa.

BOWERS, BENJAMIN NORRIS, Student Engineer, Testing Dept., General Electric Co., Schenectady, N. Y.

BRINCKERHOFF, HOWARD FRANK, Manager, Central Sta. Div., Westinghouse Elec. & Mfg. Co., 1442 Widener Bldg., Philadelphia, Pa.

*BUCHANAN, DAVID LONG, Electrical Engineer, The Philadelphia Suburban Gas & Electric Co., Wyncote, Pa.

BUFF, CARL THEODOR, Electrical Designer, Electric Bond & Share Co., 67 Broadway, New York, N. Y.

BUHL, CARL HENRY, Div. Installation Supt., Ohio Bell Telephone Co., 6205 Carnegie Ave., Cleveland, Ohio.

BURKE, ARNOLD C., Dealer & Manufacturer of X-Ray Apparatus, 9 Richmond St., E., Toronto, Ont., Can.

BURKETT, BRICE B., Dist. Service Manager, Westinghouse Elec. & Mfg. Co., 3451 E. Marginal Way, Seattle, Wash.

*BUTLER, PAUL W., Asst., Testing Laboratory, Braden Copper Co., Sewell, Rancagua, Chile, So. Amer.

BUTTERFIELD, L. BOYDSTON, Methods & Results Engineer, Western Electric Co., Inc., 309 W. Washington St., Chicago, Ill.

*CANTLEN, JAMES SAMUEL, Engineer, The Pacific Tel. & Tel. Co., 835 Howard St., San Francisco, Calif.

CAPICOTTO, JAMES VINCENT, Development Engineer, Dubilier Condenser Co., 48 West 4th St., New York, N. Y.

*CARLOVITZ, GILES HOMER, Asst. Professor of Physics, Vanderbilt University, Nashville, Tenn.

CARMICHAEL, ELWOOD T., Engg. Assistant, New York Edison Co., 15th St. & Irving Pl., New York, N. Y.; res., Elizabeth, N. J.

CASTRO-GAMBOA, FRANCISCO, Draftsman, Engg. Div., New York Edison Co., 130 E. 15th St., New York, N. Y.

CHAMBLISS, HENRY E., Electrical Engineer, Distribution Dept., Montana Power Co., Great Falls, Mont.

*CHAPMAN, HOMER HENRY, Junior Engineer, Halcomb Steel Co., Syracuse, N. Y.

CHASE, JOHN SPICER, Dist. Plant Engineer, Illinois Bell Telephone Co., 52 Forest Ave., River Forest, Ill.

CHISHOLM, HARRY EDWARD, Resident Engineer, Western Electric Co., Inc., 1505 Race St., Philadelphia, Pa.

CHRISTIAN, CHARLES JOHN, Western Electric Co., Inc., 11th & York Sts., Philadelphia, Pa.

*CLARK, HARRY FRANKLIN, Electrical Test Engineer, General Motors Research Corp., Dayton, Ohio.

CLARK, HEDLEY A., Acting Transmission Engineer, Consolidated Gas, Electric Light & Power Co., Monument & Constitution Sts., Baltimore, Md.

CLARK, JOHN A., President, Independent Electric Co., 15 N. 4th St., Minneapolis, Minn.

CLARK, JOSEPH ALOYSIUS, Senior Engineer, Brooklyn Edison Co., Inc., 561 Grand Ave., Brooklyn, N. Y.

*CLARKE, CAROLE A., Telephone Engineer, Western Electric Co., Inc., 463 West St., New York, N. Y.

CLOUTIER, LOUIS PHILIPPE, Chief Electrician, Singer Mfg. Co., St. Johns, Que., Can.

*COOK, WILBUR EARL, Engineer, Wadsworth Brick & Tile Co., Wadsworth, Ohio.

COOPER, ARCHIBALD JOHN, Sales Representative, Allis-Chalmers Mfg. Co., 50 Church St., New York, N. Y.

*COVELL, MARK B., Jr., Buyer, Purchasing Dept., Detroit Edison Co., 2000-2nd Ave., Detroit, Mich.

*COWLEY, FRANCIS CRAIG, Draftsman, Puget Sound Power & Light Co., 605 Electric Bldg., Seattle, Wash.

*CRAPO, FREDERICK MARTIN, Electrical Engineer, Indiana Steel & Wire Co., Muncie, Ind.

CRAWFORD, WILLIAM McKAIGE, Draftsman, New York Edison Co., 44 E. 23rd St., New York, N. Y.; res., West New York, N. J.
*CROOKS, HARLOW, Student Apprentice, Allis-Chalmers Mfg. Co., West Allis, Wis.
CROSSLEY, HARRY, Electrical Draftsman, Portland Railway, Light & Power Co., Portland, Ore.
*CROTHERS, FELIX ASHCROFT, Chief Electrician, Union Electric Steel Corp., Bell & Kirkwood Sts., East Carnegie; res., Pittsburgh, Pa.
*CROW, ROLLAND MILLER, Production Dept., Kansas City Power & Light Co., Northeast Station, Kansas City, Mo.
CROWLEY, JOHN C., Electrical Engineer, Western Electric Co., Inc., 463 West St., New York, N. Y.
*CUNDALL, LINCOLN ATWOOD, Electrician, Bethlehem Steel Co., Lackawanna; for mail, Buffalo, N. Y.
CUNNINGHAM, JAMES, Div. Supt. of Construction, Bell Telephone Co. of Penna., 1230 Arch St., Philadelphia, Pa.; res., Riverton, N. J.
CURLEY, MATTHEW HENRY, Electrical & Mechanical Engineer, Sterling Salt Co., Cuylerville, N. Y.
CUSHMAN, ERNEST F., Load Dispatcher, Price Bros. & Co., Ltd., Kenogami, P. Q., Can.
DAGEN, CARLTON FRANCIS, Electrical Draftsman, Utica Gas & Electric Co., 222 Genesee St., Utica, N. Y.
*DALE, IRVING HAMILTON, Inspection Foreman, Western Electric Co., Inc., 268 West 36th St., New York; res., Mt. Vernon, N. Y.
DALTON, ARTHUR GERALD, Test Engineer, Western Electric Co., Inc., 268 W. 36th St., New York; res., Bayside, N. Y.
DAY, EZRA HALSEY, Sales Engineer, Standard Underground Cable Co., 1213 N. American Bldg., Philadelphia, Pa.
*DEAN, A. L., Inspector, Philadelphia Electric Co., 2301 Market St., Philadelphia, Pa.
DEAVILLE, EDWARD, Draftsman, Hydro-Electric Power Commission of Ont., 190 University Ave., Toronto, Ont., Can.
*DE PUY, MAURICE J., Inspector, Brooklyn Edison Co., Hudson Ave. & John St., Brooklyn, N. Y.
*DICKINSON, JACKSON MILLER, Insulation Engineer, M. & P. Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
DINGLEDINE, RALPH K., Engineer, Tennessee Inspection Bureau, 1034 Stahlman Bldg., Nashville, Tenn.
DUBE, LAKSHMISHANKER BAIJNATH, Chief Electrical & Mechanical Engineer, Dwarka Cement Co., Ltd., Dwarka, Kathiawar, India.
DUNKLE, WILLIAM F., Test Engineer, Union Gas & Electric Co., West End Station, Cincinnati, Ohio.
DUNNING, SHERMAN COURTER, Treasurer, General Mgr. and Chief Engr., Carmel Light & Power Co., Inc., Carmel, N. Y.
EBBERT, ROY ORLAN, Master Mechanic, Evan Jones Coal Co., Jonesville; res., Anchorage, Alaska.
EMMONS, WILLIAM MONROE, Westinghouse Elec. & Mfg. Co., 426 Marietta St., Atlanta, Ga.
ENGELKE, LEROY JEROME, Instructor, Dept. of Elec. Engg. & Physics, U. S. Naval Academy, Annapolis, Md.
FARQUHAR, HARRY, Superintendent Service Shop, General Electric Co., 1508, 4th Ave., S., Seattle, Wash.
FENTNOR, ALBERT WALTER, Electrical Draftsman, New York Edison Co., 44 E. 23rd St., New York, N. Y.
FINLEY, HARRY ROBINSON, Div. Supervisor of Equipment, Western Union Telegraph Co., 175 Congress St., Boston; res., West Somerville, Mass.
*FINN, JAMES JEROME, Asst. Engineer, R. T. Oakes Co., 267-271 Appleton St., Holyoke, Mass.
FLUTSCH, LEO, Designer & Draftsman, Chicago, Milwaukee, & St. Paul Railway Co., Milwaukee, Wis.
FORNER, SVEN, Draftsman, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.
FOULKE, WILLING BAYARD, Sales Engr., Wagner Electric Corp., 1632 Sansom St., Philadelphia, Pa.
FOWLER, CHARLES VERN, Engineering of Power Equipment, The Pacific Tel. & Tel. Co., 820 Sheldon Bldg., San Francisco, Calif.
FOWLER, HERMAN M., Westinghouse Elec. & Mfg. Co., 3451 E. Marginal Way, Seattle, Wash.
FRAME, FLOYD HILL, Graduate Student, Worcester Polytechnic Institute, 1 Lancaster St., Worcester, Mass.
FREISEN, EDWARD CLINTON, Tester, Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., Wilkinsburg, Pa.
*FUCHS, GEORGE WILLIAM, Elec. Estimator, Philadelphia Electric Co., 1000 Chestnut St., Philadelphia; res., Yeadon, Pa.
GALLUP, C. M., Engg. Dept., The Ohio Bell Telephone Co., 4300 Euclid Ave., Cleveland, Ohio.
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Total 289.
*Formerly Enrolled Students.

**ASSOCIATES REELECTED MARCH 14, 1924**

DEE, ERNEST LEON, District Sales Manager, Edison Lamp Works of General Electric Co., Newhouse Bldg., Salt Lake City, Utah.
DOBSON, CECIL FRANK, Engineer, Wisconsin Power, Light & Heat Co., 900 Gay Bldg., Madison, Wis.
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MOONEY, FRANK P., District Superintendent, Southern California Edison Co., Redlands, Calif.
PRIESTLEY, HORACE, Mechanical & Electrical Engineer, Whakatane Borough Council, Commerce St., Whakatane, New Zealand.

**MEMBER RE-ELECTED MARCH 14, 1924**

LINDSAY, SHERWOOD COLEMAN, Engineer, Puget Sound Power & Light Co., Seattle, Wash.

**MEMBERS ELECTED MARCH 14, 1924**

BRIGGS, WILLIAM PENN, Inspector of Wires, Supt. of Street Lights & Police Signal System, Municipal Bldg., New Bedford, Mass.
BUCHANAN, OMAR BAILEY, Asst. Patent Attorney, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
EMTAGE, WILLIAM PERCY, Proprietor, The Emtage Electrical Co., Barbados, British West Indies.
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WOOD, L. A. S., Manager, Illuminating Section, George Cutter Works, Westinghouse Elec. & Mfg. Co., South Bend, Ind.

### FELLOW ELECTED MARCH 14, 1924

SAMUELS, MAURICE M., Engineer, Electrical Division, J. G. White Engineering Corp., 43 Exchange Pl., New York, N. Y.

### TRANSFERRED TO GRADE OF MEMBER MARCH 14, 1924

FRYER, R. C., Supt. Electric Meters, Union Gas & Electric Co., Cincinnati, Ohio.

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THOMAS, PHILLIPS, Research Engineer, Westinghouse Electric & Mfg. Co., Pittsburgh, Pa.

TOWLE, NORMAN L., In charge of Electrical Laboratories, Cooper Union, New York, N. Y.

### RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held March 3, 1924, recommended the following members for transfer to the grades of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

#### To Grade of Fellow

BUSH, VANNEVAR, Professor of Electric Power Transmission, Massachusetts Institute of Technology, Cambridge, Mass.

TIMBIE, WILLIAM H., Professor of Electrical Engineering & Industrial Practise, Massachusetts Institute of Technology, Cambridge, Mass.

#### To Grade of Member

ALDER, GEORGE W., Consulting Engineer, Good Housekeeping Institute, New York, N. Y.

BETTIS, ALEXANDER E., Superintendent Engineering & Construction, Kansas City Power & Light Co., Kansas City, Mo.

De CAMP, SAMUEL M., Local Engineer, General Electric Co., Kansas City, Mo.

MEHARG, LAURENCE, Chief Engineer, Hazel-Atlas Glass Co., Wheeling, W. Va.

OLSEN, EDWARD A., Superintendent of Operation, Alexandria Light & Power Co., Alexandria, Va.

RETT, CARL E., Chief Engineer, Lambert Tire & Rubber Co., Barberton, Ohio

RICHARDS, KEENE, Industrial Engineer, Detroit, Mich.

SCHAEFER, CLARENCE C., Traffic Engineer-Operation, Philadelphia Rapid Transit Co., Philadelphia, Pa.

### APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before February 29, 1924.

Adams, J. A., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Auxer, F. P., The National Telephone Supply Co., Cleveland, Ohio
Avery, M. B., (Member), Rochester & Syracuse Railroad Co., Newark, N. J.
Beaulieu, L. E., General Electric Co., Lynn, Mass.
Beckwith, G. S., New York Telephone Co., New York, N. Y.
Berry, J. B., Cumberland Tel. & Tel. Co., Nashville, Tenn.
Beutler, E. C., New York Edison Co., New York, N. Y.
Bonn, F. G., Hammond Cedar Co., Ltd., Port Hammond, B. C.
Bredahl, A. C., C. M. S., Inc., Tarrytown, N. Y.
Brent, D. J., West Penn Power Co., Pittsburgh, Pa.
Buys, I., Kansas Gas & Electric Co., Wichita, Kans.
Cady, J. J., Electrician, 65 W. 3rd St., S. Boston, Mass.
Campbell, C. C., Pacific Gas & Electric Co., San Francisco, Calif.
Carr, J. L., General Electric Co., Washington, D. C.
Carroll, H. A., General Electric Co., Lynn, Mass.
Chapman, H. E., Southern New England Tel. Co., Hartford, Conn.
Christman, C. W., Brooklyn Edison Co., Brooklyn, N. Y.
Cleminshaw, R. H., (Member), Cleveland Elec. Motor Co., Cleveland, Ohio
Cochran, R. D., Iowa Light, Heat & Power Co., Orange City, Iowa
Cook, T. J., American Tel. & Tel. Co., Atlanta, Ga.
Crane, A. S., Public Service Electric Co., Newark, N. J.
Danner, E. Y., University of Washington, Seattle, Wash.
Decker, C. R., Hudson Coal Co., Scranton, Pa.
Denroche, W. E., Wagner Electric Co. of Canada, Ltd., Toronto, Ont.
Dusinberre, H. W., U. S. S. Arkansas, c/o Postmaster, New York, N. Y.
Eiler, E. E., (Member), Capt., U. S. M. C., Marine Barracks, Quantico, Va.
Engel, T. J., Western Electric Co., New York, N. Y.
Evans, A. J., New York Edison Co., New York, N. Y.
Ewing, R., Westinghouse Elec. & Mfg. Co., Detroit, Mich.
Ferro, D. E., Stevens & Wood, New York, N. Y.
Finney, T. J., Jr., 87 Schuyler Ave., Stamford, Conn.
Finnicum, J. L., Western Electric Co., Inc., Pittsburgh, Pa.
Fletcher, E. L., New York Telephone Co., New York, N. Y.
Fry, L. C., General Electric Co., Lynn, Mass.
Ganey, L. T., American Tel. & Tel. Co., New York, N. Y.; res., Salem, Mass.
Gerge, N. E. G., Royal Swedish Legation, Mexico, D. F., Mex.
Gerken, J. H., Robt. E. Denike, Inc., New York, N. Y.
Gilman, E. F., Wood Worsted Mill, Lawrence, Mass.
Grady, E. A., Ohio Bell Tel. Co., Columbus, Ohio
Gray, P. F., Canadian General Electric Co., Toronto, Ont.
Greif, J. H., Manhattan Electric Supply Co., Jersey City, N. J.
Gross, C. G., Eastern Laboratory, Inc., New York, N. Y.
Hackett, G. R., General Electric Co., Schenectady, N. Y.
Halsey, F. C., Radio Corp. of America, Port Jefferson, N. Y.
Harris, L. F., New York Telephone Co., New York, N. Y.
Hatfield, H. F., Penn. Power & Light Co., Harwood Mines, Pa.
Henry, R. T., The Niagara Falls Power Co., Niagara Falls, N. Y.
Herr, E. D., Pennsylvania Railroad Co., Long Island City, N. Y.
Herrley, B. G., The College of the City of New York, New York, N. Y.
Hickson, J. I., with H. J. C. Pearson, Atlanta, Ga.
Hokanson, C. L., Dwight P. Robinson & Co., Inc., New York, N. Y.
Hulley, L. W., New York Telephone Co., New York, N. Y.
James, L. H., Hudson Coal Co., Scranton, Pa.
Jensen, B. O. H., Westinghouse Elec. & Mfg. Co., Newark, N. J.
Jones, A. E., Irvington Varnish & Insulator Co., Irvington, N. J.
Kramer, A. E., Thos. E. Murray, Inc., New York, N. Y.
Ladge, M., Electrician, 58 Leverett St., Boston, Mass.
Leavitt, L. S., The Lowell Electric Light Corp., Lowell, Mass.
Lothrop, E. F., General Electric Co., Lynn, Mass.
MacWhinnie, D. T., New York Tel. Co., New York, N. Y.
Martin, F. L., Duquesne Light Co., Cheswick, Pa.
Mason, H. H., Atlantic City Electric Co., Atlantic City, N. J.
Maxwell, G. W., American Radio & Research Corp., Medford Hillside, Mass.
Mayer, V. W., General Electric Co., Baltimore, Md.
McAvoy, W. H., Dwight P. Robinson & Co., Inc., New York, N. Y.
Mears, C. B., Philadelphia Electric Co., Philadelphia, Pa.
Meyer, C. A., Sargent & Lundy, Chicago, Ill.
Morrissey, J. P., (Member), J. P. Morrissey, Inc., New York, N. Y.
Mott, F. S., Goodman Mfg. Co., Chicago, Ill.
Nelson, A. E., New York Telephone Co., New York, N. Y.
Newell, F., West Indies & Panama Telegraph Co., Ltd., St. Thomas, Virgin Islands of U. S. A.
Nolan, C. E., The Bristol Co., Waterbury, Conn.
Nordlien, B. W., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Nordlin, H. W., Western Electric Co., Inc., Winchendon, Mass.
Owens, L. H., 3542 N. 23rd St., Philadelphia, Pa.
Pagliuca, S., Apco Mfg. Co., Providence, R. I.
Pankhurst, F. A., Dominion Bridge Co., Ltd., Lachine, P. Q., Can.
Pearson, D. M., Pacific Tel. & Tel. Co., San Francisco, Calif.
Pierson, W. H., New York Telephone Co., New York, N. Y.
Plaisted, G. E., General Electric Co., Schenectady, N. Y.
Pokorney, J. J., Westinghouse Elec. & Mfg. Co., Cleveland, Ohio
Powers, R. A., General Electric Co., W. Lynn, Mass.
Pye, H. C., Automatic Electric Co., Chicago, Ill.
Radcliffe, T. J., Edison Lamp Works, Harrison, N. J.
Raynor, H. S., New York Telephone Co., New York, N. Y.
Rearden, J. R., Southern Bell Tel. & Tel. Co., Jacksonville, Fla.
Reichel, W. A., Public Service Production Corp., Newark, N. J.
Reynolds, H. B., Interborough Rapid Transit Co., New York, N. Y.
Robinson, C. E., Standard Steel Works Co., Burnham, Pa.
Rosenkranz, J. A., National Automotive School, Los Angeles, Calif.
Roskelley, C. O., Engineer, 1st National Bank, Brigham, Utah
Rowland, A., Toronto Hydro-Electric System, Toronto, Ont.
Ruby, M. S., (Fellow), City Manager, City of Lubbock, Lubbock, Texas
Sandig, G. C., Public Service Co. of Colorado, Denver, Colo.
Sands, J. W., International Nickel Co., Bayonne, N. J.
Schnapp, M. H., General Electric Co., San Francisco, Calif.
Schroder, J. H., Public Service Production Co., Newark, N. J.
Schubert, H., Philadelphia Electric Co., Philadelphia, Pa.
Schuhmann, W. J., Roller-Smith Co., New York, N. Y.
Scott, H. S., Kentucky & West Virginia Power Co., Sprigg, W. Va.
Sen, R. C., General Electric Co., West Lynn, Mass.

Singer, J. I., Ohio Public Service Co., Alliance, Ohio
Smalley, O. D., Iowa State College, Ames, Iowa
Smith, A. M., Kansas City Power & Light Co., Kansas City, Mo.
Smith, C. L., with H. E. William, Vancouver, B. C.
Smith, J. B., W. T. Henley's Telegraph Wks., Ltd., London, Eng., Mexico City, Mex.
Snowden, J. W., Jr., New York Telephone Co., New York, N. Y.
Somers, F. W., Cline Electric Mfg. Co., Chicago, Ill.
Sorensen, A. C., New York Telephone Co., New York, N. Y.
Stegeman, G. A., Jr., Metropolitan Edison Co., Reading, Pa.
Thayer, R. J., Willard Storage Battery Co., Cleveland, Ohio
Thiedemann, T., Havana Elec. Ry., Lt. & Pr. Co., Havana, Cuba
Thomas, E. E., General Electric Co., Schenectady, N. Y.
Uhl, Harry C., General Electric Co., Schenectady, N. Y.
Van Auken, R. S., General Electric Co., Ft. Wayne, Ind.
Warren, R. M., (Member), Dubilier Condenser & Radio Corp., New York, N. Y.
Weiland, C. F., (Member), Consumers Power Co., Jackson, Mich.
Werner, W. S., The Kelley-Koett Mfg. Co., Covington, Ky.
Wichman, M. F., Northwestern Bell Telephone Co., Minneapolis, Minn.
Woodward, C. V., Westinghouse Elec. & Mfg. Co., Baltimore, Md.
Worley, J., Mo. School of Mines & Metallurgy, Rolla, Mo.
Wurzback, H. E., Magna Plant Utah Copper Co., Magna, Utah

Total 122

**Foreign**

Allen, V., Carlos, Mexican Corp., Fresnillo, Zac., Mexico
Chatterjee, S., Bombay, Baroda & Central India Railway, United Provinces, India
Ghersa, U., Instalaciones Interiores de la Compania Italo Argentina de Electricidad, Buenos Aires, S. A.
Knight, R., Bombay, Baroda & Central India Railway, Bulsar, India
Kondo, H., Shibaura Engineering Works, Shibaku, Tokyo, Japan
Nash, H. J., Bombay, Baroda & Central India Railway, Bombay, India
Tsuruta, S., Denki-kagaku Kogyo Kaisha, Tokyo, Japan
Walker, E. W., Electric Machinery Co., Ancoats, Manchester, Eng.

Total 8

## STUDENTS ENROLLED DECEMBER 14, 1923

18597 Lyon, Warren A., Syracuse University
18598 Hovgaard, Ole M., Mass. Institute of Technology
18599 Rettig, Harlow W., Ohio State University
18600 Willis, George E., University of Delaware
18601 Reilly, J. Harry, Stevens Institute of Technology
18602 Dixon, Henry Marshall, Jr., University of Virginia
18603 Echols, G. H., University of Virginia
18604 Moore, Stephen N., University of Virginia
18605 Smith, George T., University of Virginia
18606 Long, Holbert H., University of Virginia
18607 Hart, Robert W., Mass. Institute of Technology
18608 Anderson, Duncan B., Clarkson College of Technology
18609 Augustine, Edward T., Clarkson College of Technology
18610 Burns, Walter J., Clarkson College of Technology
18611 Coakley, George W., Clarkson College of Technology
18612 Dempsey, George J., Clarkson College of Technology
18613 Donovan, Donald H., Clarkson College of Technology
18614 Howland, J. Harvey, Clarkson College of Technology
18615 Krug, John P., Clarkson College of Technology
18616 Lamb, Vincent G., Clarkson College of Technology
18617 Mahoney, Joseph M., Clarkson College of Technology
18618 Malotte, Archibald J., Clarkson College of Technology
18619 Maxson, Donald A., Clarkson College of Technology
18620 Merrill, Lynn L., Clarkson College of Technology
18621 Nims, Kenneth E., Clarkson College of Technology
18622 Power, Earl W., Clarkson College of Technology
18623 Sullivan, Verne L., Clarkson College of Technology
18624 Taylor, Allan J., Clarkson College of Technology
18625 Williams, Kenneth F., Clarkson College of Technology
18626 Wring, William B., Clarkson College of Technology
18627 Canfield, Orra W., University of British Columbia
18628 Graham, Roland C., University of British Columbia
18629 Heaslip, Wilbur J., University of British Columbia
18630 Peele, John P. F., University of British Columbia
18631 Stacey, Leonard B., University of British Columbia
18632 Underhill, John E., University of British Columbia
18633 Longfellow, Harold R., University of Illinois
18634 West, Frank R., University of Maine
18635 Maylott, Carleton F., Worcester Polytechnic Institute
18636 Morse, Albert W., University of Minnesota
18637 Wolfe, George E., University of Minnesota
18638 Ludlum, R. V., University of Minnesota
18639 Johnson, R. B., University of Minnesota
18640 Matheson, George A., Rhode Island State College
18641 Button, Charles T., University of Cincinnati
18642 MacGuffie, Charles T., Pennsylvania State College
18643 Mainero, Alfred V., University of Santa Clara
18644 Hirsch, Louis H., University of Illinois
18645 Wolf, Frank L., Pennsylvania State College
18646 Cochran, Glenn W., University of Michigan
18647 Hediger, Frederick, University of Michigan
18648 Brown, Harold R., University of Washington
18649 Crosby, Roy H., University of Washington
18650 Ecker, Anthony J., University of Washington
18651 Turner, Arthur F., University of Washington
18652 Davis, Caleb F., University of Washington
18653 Fall, James D., University of Washington
18654 Williamson, Theodore, University of Texas
18655 McGuinness, Daniel J., Montana State College
18656 Waller, John L., Univeristy of Tennessee
18657 Andreae, Stephan C., University of Wisconsin
18658 Brosnan, Thomas J., Catholic University of America
18659 Bultman, William B., Catholic University of America
18660 Coggins, Harold E., Catholic University of America
18661 Coughlin, John G., Catholic University of America
18662 Crowe, Thomas J., Catholic University of America
18663 Dean, George F., Catholic University of America
18664 Freney, James J., Catholic University of America
18665 Gannon, Joseph T., Catholic University of America
18666 Greemley, William T., Catholic University of America
18667 Dolan, Joseph W., Catholic University of America
18668 Heltman, Charles C., Jr., Catholic University of America
18669 Kennedy, Anthony J., Catholic University of America
18670 Kirby, Carroll G., Catholic University of America
18671 Larranaga, Vincent H., Catholic University of America
18672 May, Albert, Catholic University of America
18673 McEneany, Joseph F., Catholic University of America
18674 Monserrate, Juan R., Catholic University of America
18675 Nicholson, Robert F., Catholic University of America
18676 Prior, John P., Catholic University of America
18677 Shea, Dennis C., Jr., Catholic University of America
18678 Tomelden, Arthur A., Catholic Univeristy of America
18679 Williamson, Kenneth T., Catholic University of America
18680 Robinson, George G., University of Illinois
18681 Irish, James C., Worcester Polytechnic Institute
18682 Jones, Floyd K., Lewis Institute
18683 Ross, Maurice B., California Institute of Technology
18684 Wilson, Ralph C., California Institute of Technology
18685 McCann, Augustus R., University of Wisconsin
18686 Brown, Charles R., Johns Hopkins University
18687 Harrison, Wallace, University of Tennessee
18688 Dunkin, Jacob, Washington State College
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18692 Gardey, Erhardt, University of Illinois
18693 Payne, Roy B., Worcester Polytechnic Institute
18694 Boerlin, Irving C., Pennylvania State College
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18698 Gill, Aubrey C., Alabama Polytechnic Institute
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18700 Guedalia, Jules, Columbia University
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18702 Backus, Clyde H., State College of Washington
18703 Miller, Delbert D., State College of Washington
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18706 Traub, Loren A., State College of Washington
18707 Browning, Glenn H., Harvard University
18708 Quinlan, Robert E., Worcester Polytechnic Institute

18709 Warner, Arthur K., State College of Washington
18710 Gayle, James DeJ., Virginia Polytechnic Institute
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18713 Callaham, William E., Virginia Polytechnic Institute
18714 Rolfe, John T., Virginia Polytechnic Institute
18715 McClung, Francis L., Virginia Polytechnic Institute
18716 Williams, Roy M., Virginia Polytechnic Institute
18717 Venable, Bennett M., Virginia Polytechnic Institute
18718 Ericson, Harry B., Colorado State Agricultural College
18719 Inman, Donovan E., Colorado State Agricultural College
18720 Graf, Ervin W., Washington State College
18721 Osius, Edgar F., University of Wisconsin
18722 Porter, Roy G., Kansas State Agricultural College
18724 Long, Forest A., Engineering School of Milwaukee
18725 Fishel, William J., Engineering School of Milwaukee
18726 Sear, Raymond S., Engineering School of Milwaukee
18727 Eckardt, Marcel V., Engineering School of Milwaukee
18728 Carrel, William E., Engineering School of Milwaukee
18729 Foster, Lee R., Virginia Polytechnic Institute
18730 Leonard, Robert N., Cornell University
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18732 Utterback, Austin L., University of Illinois
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18734 Miller, Carroll deV., Purdue University
18735 Rannells, William J., Purdue University
18736 Hollis, Irvin H., Purdue University
18737 Cloud, Dudley H., Washington State College
18738 Regli, Joseph H., Drexel Institute
18739 Dunbar, Howard K., Union College
18740 Arthur, Richard S., Union College
18741 Percy, F. W., University of Arizona
18742 Lecron, Albert, Mass. Institute of Technology
18743 Middleton, Richard A., Drexel Instutute
18744 Wiatt, John E., Alabama Polytechnic Institute
18745 Payne, John E., Alabama Polytechnic Institute
18746 Johnson, Jesse P., Alabama Polytechnic Institute
18747 Hooper, William E., Alabama Polytechnic Institute
18748 Wadia, Rustom D., Union College
18749 Huntley, Edison D., Union College
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18751 Hearding, William S., University of Michigan
18752 Weber, Edward L., State University of Iowa
18753 Eaton, Wayne G., University of Colorado
18754 Dressor, Charles F., University of Colorado
18755 Wrigley, James B., Oklahoma Agricultural & Mechanical College
18756 Ritchie, Russell E., University of Wisconsin
18757 Kisner, Albert G., West Virginia University
18758 Wilson, James A., University of Arizona
18759 Bergevin, William P., Rennselaer Polytechnic Institute
18760 Brown, Nelson E., Rensselaer Polytechnic Institute
18761 Brownlee, Theodore, Rensselaer Polytechnic Institute
18762 Eichenberger, Walter G., Rensselaer Polytechnic Institute
18763 Giering, Percival L., Rensselaer Polytechnic Institute
18764 Hanford, J. Ralph, Rensselaer Polytechnic Institute
18765 Havourd, Russell M., Rensselaer Polytechnic Institute
18766 Helfter, Franklin S., Rensselaer Polytechnic Institute
18767 Hilbert, Edwin W., Rensselaer Polytechnic Institute
18768 Jatlow, Jacob L., Rensselaer Polytechnic Institute
18769 Kaplan, Samuel, Rensselaer Polytechnic Institute
18770 Kristan, Peter, Jr., Rensselaer Polytechnic Institute
18771 Lewis, Josiah G., Rensselaer Polytechnic Institute
18772 Mallet, Montville B., Rensselaer Polytechnic Institute
18773 Mellon, James J., Rensselaer Polytechnic Institute
18774 Morran, J. Burdette, Rensselaer Polytechnic Institute
18775 Mowrey J. Herman, Rensselaer Polytechnic Institute
18776 Perkinson, Thomas F., Jr., Rensselaer Polytechnic Institute
18777 Rose, Chester E., Rensselaer Polytechnic Institute
18778 Rosenburg, Everett R., Rensselaer Polytechnic Institute
18779 Ruoff, George J., Rensselaer Polytechnic Institute
18780 Sager, George F., Rensselaer Polytechnic Institute
18781 Singleton, Isiah C., Rensselaer Polytechnic Institute
18782 Van Ness, Roy W., Rensselaer Polytechnic Institute
18783 Putman, Allen L., Drexel Institute
18784 Layer, S. Furman, Drexel Institute
18785 Davey, Ross C., Mass. Institute of Technology
18786 Yasumura, Jobo, State College of Washington
18787 Lenz, George A., Union College
18788 Gardiner, Charles E., Jr., Union College
18789 Lottridge, Richard W., Union College
18790 Mueller, Francis C., Oregon Agricultural College
18791 Miller, Dalton W., Oregon Agricultural College
18792 Bauer, Charles, Newark Technical School
18793 Stewart, Rudolph J., Oregon Agricultural College
18794 Atanasoff, John V., University of Florida
18795 Bearss, Cylde I., University of Florida
18796 Friedman, J. W., University of Florida
18797 Levy, Emanuel M., University of Florida
18798 Nichols, Wesley W., University of Florida
18799 Peeples, Earl E., University of Florida
18800 Schroeder, Henry W., Washington State College
18801 Willits, William M., Lafayette College
18802 Apker, Charles L., University of Pennsylvania
18803 Brainerd, John G., University of Pennsylvania
18804 Cook, Willard G., University of Pennsylvania
18805 Hanaw, Justin J., University of Pennsylvania
18806 Krauss, Ralph A., University of Pennsylvania
18807 Smith, William P., University of Pennsylvania
18808 Hart, Gerald E., State College of Washington
18809 Sorenson, Harold J., University of Nevada
18810 Brunner John F., University of Washington
18811 Ravelli, Henri J. A., University of Washington
18812 Church, Richard A., University of Washington
18813 Hoard, Bert V., University of Washington
18814 Hanan, Merlin J., University of Washington
18815 Lamay, Urban R., Worcester Polytechnic Institute
18816 Michas, Constantine D., Brooklyn Polytechnic Institute
18817 Donald, Douglas D., Mass. Institute of Technology
18818 Larsson, Ralph T., Worcester Polytechnic Institute
18819 Begg, Ellis L., Oregon State Agricultural College
18820 Minott, David J., Worcester Polytechnic Institute
18821 Harrison, George O., University of Florida
18822 Lent, Worthington C., Union College
18823 Botsford, Nelson, Union College
18824 Moore, Raymond D., Union College
18825 Overton, Theodore D., University of Nevada
18826 Kjolseth, Knud E., Union College
18827 Dodd, Frank J., Jr., Georgia School of Technology
18828 Durham, Albert C., Georgia School of Technology
18829 Epting, Harry D., Georgia School of Technology
18830 Gaines, John M., Georgia School of Technology
18831 Patton, Leslie K., Georgia School of Technology
18832 Rooks, William A., Jr., Georgia School of Technology
18833 Rumble, Alfred R., Georgia School of Technology
18834 Woods, Don E., Georgia School of Technology
18835 Evans, James C., Mass. Institute of Technology
18836 Mackintosh, Donald C., Union College
18837 Anderson, Raymond L., Tri-State College
18838 Dave, Shrikrishna B., Tri-State College
Total 241

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U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION
U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION
COMMISSION OF WASHINGTON AWARD

# DIGEST OF CURRENT INDUSTRIAL NEWS

## NEW CATALOGUES AND OTHER PUBLICATIONS

*Mailed to interested readers by issuing companies.*

**Small Motor Starter.**—Bulletin 58, 4 pp. Describes a fractional horse power starter, with low-voltage protection for direct-current motors. Ward Leonard Electric Company, Mount Vernon, N. Y.

**Small Motor Controllers.**—Bulletin 57, revised, 4 pp. Describes Vitrohm fractional horse power armature speed controllers of the embedded resistor, fully enclosed type, and embedded resistor, exposed contact type. Ward Leonard Electric Company, Mount Vernon, N. Y.

**The Triumph Electric Company, Cincinnati, O.,** announces a complete revision of the prices covering its entire line of motors, both a. c. and d. c., from 1 h. p. to 250 h. p., effective March 1. The new price books are now available.

**Transformer Data.**—The Moloney Electric Company, St. Louis, Mo., has begun the publication of a series of bulletins containing technical and semi-technical information in regard to transformers, their connections, impedance, polarity, etc. The first issue of the series contains the simple single-phase connections of standard distribution transformers.

**Boilers.**—Catalog, 270 pp., describing the Kidwell Two-Flow Ring-Circuit Water Tube Boiler. The book, which is profusely illustrated, explains the principles underlying boiler design and operation, their application to boiler analysis, and how they are applied in the design of the Kidwell boiler. The Kidwell Boiler Company, Milwaukee, Wis.

**Compensating Coil.**—Bulletin 110, 12 pp., describes an improved and practical device for direct-current switchboard ammeters, which makes alloy shunts unnecessary. Through the use of the compensating coil it is possible to utilize a section of the copper conductor itself for the ammeter shunt. This device increases ammeter accuracy and reduces the cost of installation. Minerallac Electric Company, 1045 Washington Boulevard, Chicago, Ill.

**Supervisory Control.**—Circular 1694, 8 pp. Sets forth the general principles of operation and construction of both audible and visual systems of supervisory control for automatic substations. The audible system is suitable for the distant control of small hydroelectric generating stations, small automatic switching or distributing stations, or small interurban railway substations. In this system signals are transmitted so that the operator can hear them. Its features are simplicity and low cost. The form of control developed for larger systems with automatic substations requiring a great number of operations, is known as the visual system. This requires much less attention on the part of the operator than does the audible system, because it gives him a continuous visible record of the operating conditions. Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

## NOTES OF THE INDUSTRY

**The General Radio Company, Cambridge, Mass.,** have purchased 20,000 feet of land adjacent to their present factory and will start construction at once on a four-story concrete building. This new unit will have the same capacity as their present building, thus doubling their present facilities.

**Condit Electrical Manufacturing Company, South Boston, Mass.,** has recently appointed the following representatives: Shook & Fletcher Supply Company, Birmingham, for the state of Alabama; Ward Engineering & Battery Company, Jacksonville, for the state of Florida; and E. A. Thormwell, Atlanta, for the state of Georgia.

**Outdoor Bus Connectors.**—The Burndy Engineering Company, 10 East 43rd Street, New York, has designed and is patenting a series of T-Connectors to be used for outdoor substation conductors. These embody features whereby full electrical contact is maintained during severe weather conditions, switching or other disturbances. A gravity lock makes them independent of possible bolt failures. Other devices to be used in conjunction with outdoor substation equipment are in the process of development. A. B. Dibner, formerly with the Electric Bond & Share Company, has been appointed sales engineer of the Burndy Company.

**Universal Welding Machine.**—The Electric Arc Cutting and Welding Company, Newark, N. J., has placed on the market a new model welder, which will operate on any industrial power supply. The new unit is no larger than the type previously manufactured by this company, which has always been applicable to one or two voltages, such as 110-220 or 220-440. As an illustration of the adaptability of the new welder, the 110-220-440 volt combination is obtained by multiple, series multiple and series combinations of the coils of the primary winding. To make the same machine operate on 25 and 40-cycles, taps and adaptor windings are used to obtain the proper electrical characteristics. The apparatus is also operative on 110 and 220 volts d. c. by means of a resistor-reactor combination inserted in the secondary winding. Some of the machines have been in operation for two years.

**Unique Transformers for Brooklyn Edison Company.**—As part of a more than two-million dollar order received from the Brooklyn Edison Company, the Westinghouse Electric & Manufacturing Company recently shipped from its East Pittsburgh plant, twenty large oil insulated, self-cooled transformers of unique construction. Eighteen of these transformers are rated at 10,000 kv-a. three-phase, 60-cycles, and two at 6,000 kv-a. three-phase , 60-cycles; and they differ from previous transformers of similar capacity in that, instead of being equipped with the usual porcelain bushing for high and low-voltage leads, these leads are taken out through potheads on the side of the tank near the top. The connections are made in the pothead, thus eliminating exposed connections and any possible grounding that might occur through human contact or through anything touching the connection. The transformers are the first built by the Westinghouse Company with this construction and are the largest so equipped in existence in the United States.

**New General Electric Service Shops.**—A recent review of the supply and repair parts required in connection with the great variety of apparatus manufactured by the General Electric Company has led to the establishment of a wider and more adequate group of service and repair shops in the United States. In addition to the service and repair shops maintained at all General Electric factories, thoroughly equipped shops have been installed and are in operation at the following points: Atlanta, Chicago, Los Angeles, New York, Kansas City, Minneapolis, Oakland, Philadelphia, St. Louis and Seattle. The personnel and facilities of these shops prepares them for any form of service work on machines up to 500 h. p. In some of the larger shops apparatus of any size can be serviced. These shops are also prepared to furnish competent men on short notice, in case of accidents or for any emergency work. An enlarged system of distributing replacement and supply parts is also in effect.

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**John F. Alvord,** founder and owner of the Electric Arc Cutting and Welding Company, Newark, N. J., died on March 13. At the time of his death he did not actively participate in the conduct of the business. Mr. Alvord was also the owner of the Splitdorf Electrical Company, Newark, N. J., The Torrington Company, Torrington, Conn., Wire Wheel Corporation of America, Buffalo, N. Y., and Hendee Manufacturing Company, Springfield, Mass.